

individual ecological receptors (e.g., compared to ecologically based screening levels). However, results of INL Site biotic sampling conducted as part of INL Site environmental monitoring programs were used to assess transport of contaminants from subsurface to surface soil, to locations outside the SDA, and into the food web.

E-1.1.4.8 Nature and Extent of Contamination—Conclusions. Evaluation of the nature and extent of contamination concludes that low concentrations of carbon tetrachloride are affecting the aquifer near the SDA. Carbon tetrachloride has been detected slightly above the MCL, but concentrations appear to be leveling off, which may be the result of vapor vacuum extraction by the Organic Contamination in the Vadose Zone Project (i.e., Operable Unit-7-08).

Several other contaminants buried in the SDA have been detected at low concentrations in the vadose zone and may be migrating. Most vadose zone detections are in the interval above the B-C interbed. Highest densities were detected in the vadose zone beneath Pit 5 and Pad A and in the western end of the SDA. The most frequently detected contaminants in the vadose zone are VOCs, uranium isotopes, nitrate, Tc-99, and C-14. In addition, Sr-90, Cl-36, Pu-238, Am-241, I-129, and Pu-239/240 have been detected sporadically at concentrations near detection limits.

The monitoring network has been greatly expanded since 1998, with the addition of more than 300 probes in the waste, 62 vadose zone lysimeters, five upgradient aquifer wells, and an aquifer monitoring well inside the SDA. Additional vapor ports also have been installed, bringing the total to 212, 174 of which are sampled routinely. Concentrations in the environment around the SDA will continue to change over time due to several factors. Examples include:

- Remedial actions at the SDA could affect concentrations in the environment (e.g., beryllium block grouting will reduce C-14 concentrations in the vadose zone)
- Continued operation of the Operable Unit 7-08 vapor vacuum extraction and treatment system removes VOCs from the vadose zone
- Subsidence repairs and surface contouring reduce migration by decreasing the amount of infiltration through the waste and into the subsurface
- Degradation of waste packages also influences measured concentrations (e.g., as containers fail over time, more contamination is available for transport to the surface by plants and animals or into the subsurface with infiltration).

E-1.1.5 Summary of Section 5—Contaminant Fate and Transport

Section 5 addresses modeling of contaminant source release, potential routes of contaminant migration and persistence for the subsurface pathway, and methodology for determining rate constants used in the biotic model. Complete exposure pathways defined by the conceptual site model led to three types of models: source release, subsurface transport, and biotic transport. Persistence of contaminants in the environment was evaluated based on contaminant mobility controlled by dissolved-phase transport, vapor-phase transport, and biotic transport by animals and plants intruding into the waste.

Modeling presented in Section 5 uses best-estimate inventories as the basis for analyzing baseline risk in Section 6. These models also will be used to support remedial decisions for Operable Unit 7-13/14 by simulating long-term effectiveness of various remedial actions. Many aspects of the source-release and groundwater pathway modeling have been improved compared to the ABRA model. However, uncertainties are and always will be associated with predicting movement of contaminants; therefore,

conservatism is retained in the modeling and is demonstrated through comparison to monitoring. The primary improvement over the ABRA model is incorporation of additional information into the source-release model regarding inventory, waste streams, and disposal locations within the SDA. These improvements and results from additional characterization have been incorporated into the source-release model and its interface with the vadose zone model. Improvements also have been made in groundwater pathway modeling; however, those improvements have had less impact on predicted concentrations. For groundwater pathway modeling, the primary improvements were updating the VOC modeling and including gaseous-phase C-14 transport.

Eighteen source areas were defined for implementation in the source-release model (see Figure E-6). The source-term model simulated release of contaminants into the subsurface from buried waste. The DUST-MS code^a (Sullivan 1992) was used to simulate release of contaminants of potential concern and their long-lived decay-chain products. Simulated mass-release mechanisms comprised surface washoff, diffusion, and dissolution. Release mechanisms were identified based on waste-stream-specific data. Output from the source-release model provided input to both the biotic-transport and subsurface-transport models.

Fate and transport of both dissolved-phase and vapor-phase contaminants in the SDA subsurface were modeled with the three-dimensional TETRAD simulator (Shook 1995). Beginning with contaminant fluxes received as input from the source-release model, the TETRAD model simulates movement of contaminants in the vadose zone down to the aquifer and subsequent aquifer transport. Figure E-7 shows three-dimensional views of the vadose zone base grid and the first- and second-level grid refinements. Simulations produced estimates of future contaminant concentrations in groundwater. The model was parameterized in consultation with modeling staff from DEQ and EPA, as reflected in values presented in the Second Addendum to the Work Plan (Holdren and Broomfield 2004). Site-specific data describing lithology, spatially variable infiltration, sorption, and other characteristics were applied, where available. Contaminant transport in the aquifer was simulated until peak aquifer concentrations were achieved or to a maximum of 10,000 years. Sensitivity cases were modeled to evaluate effects of upper-bound inventories and additional selected parameters on estimated media concentrations and risk.

The DOSTOMAN code was used to estimate surface soil concentrations produced by biotic transport of contaminants to the surface by plants and animals. Rate constants and other input parameters used in the code (e.g., rooting depths) were selected from current literature, giving preference to site-specific values for the SDA and the INL Site, when available. The biotic model was not calibrated because surface soil at the SDA is routinely redistributed through contouring and operations and because of the fundamental assumption that remedial action at the SDA will include a surface barrier (Holdren and Broomfield 2004). The DOSTOMAN model soil concentrations were estimated for the current timeframe and for future human health and ecological exposure scenarios.

Sensitivity simulations showed that source inventory and the type of mass-release mechanism (i.e., surface washoff, diffusion, and dissolution) have the largest impact on predicted contaminant concentrations in environmental media. The amount of infiltration through the waste and the low-permeability region in the aquifer are two other model features that significantly affect predicted groundwater concentrations. The amount of water that contacts waste influences groundwater pathway concentrations. Water is the driving force that moves aqueous-phase contaminants along the groundwater pathway. Sensitivity simulations show that additional water in the vadose zone, which does not contact waste, primarily dilutes groundwater pathway concentrations. The low-permeability region in the aquifer also substantially impacts predicted concentrations by reducing dilution that would otherwise occur, thus

a. References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government, any agency thereof, or any company affiliated with the INL Site.

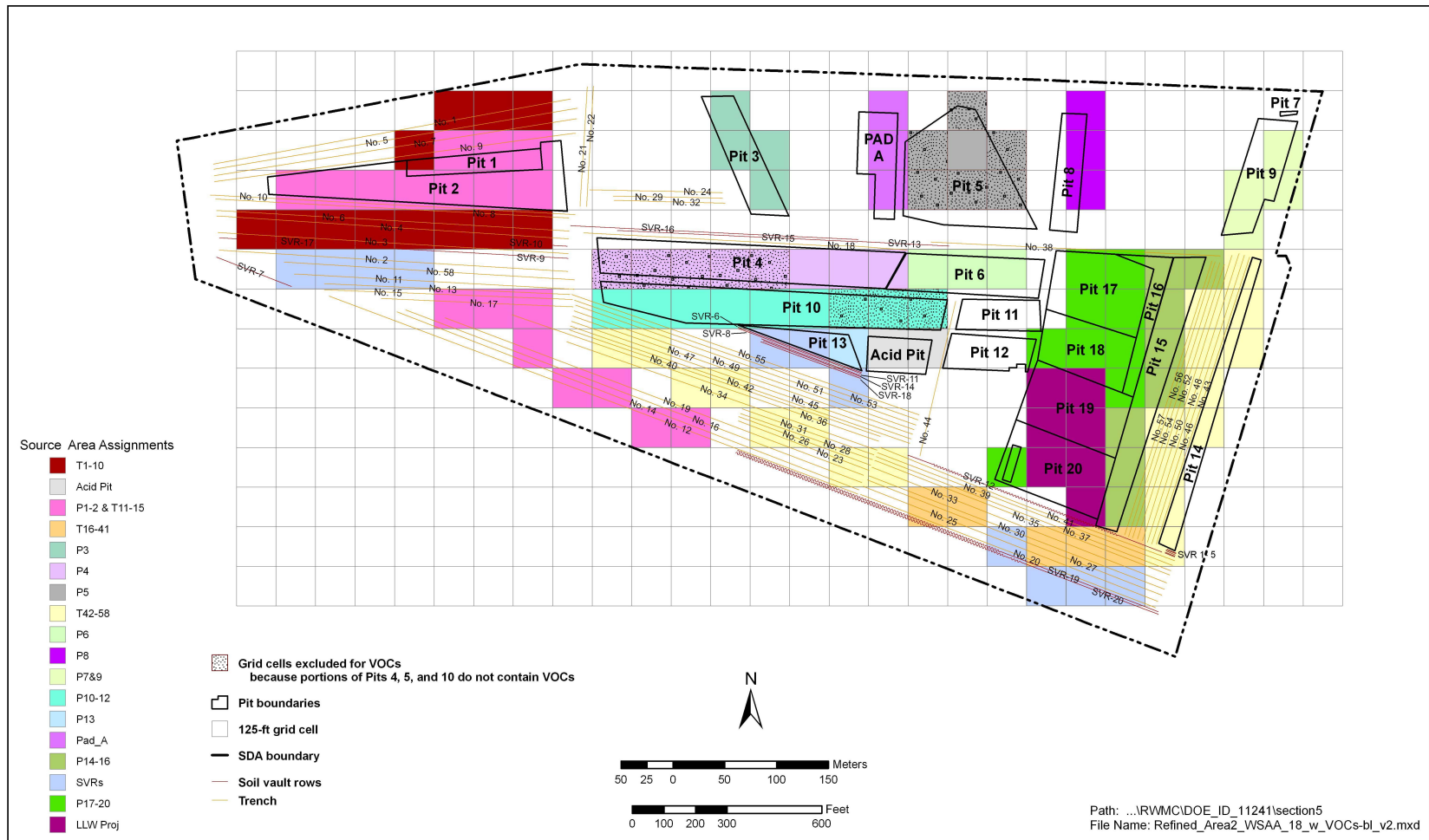
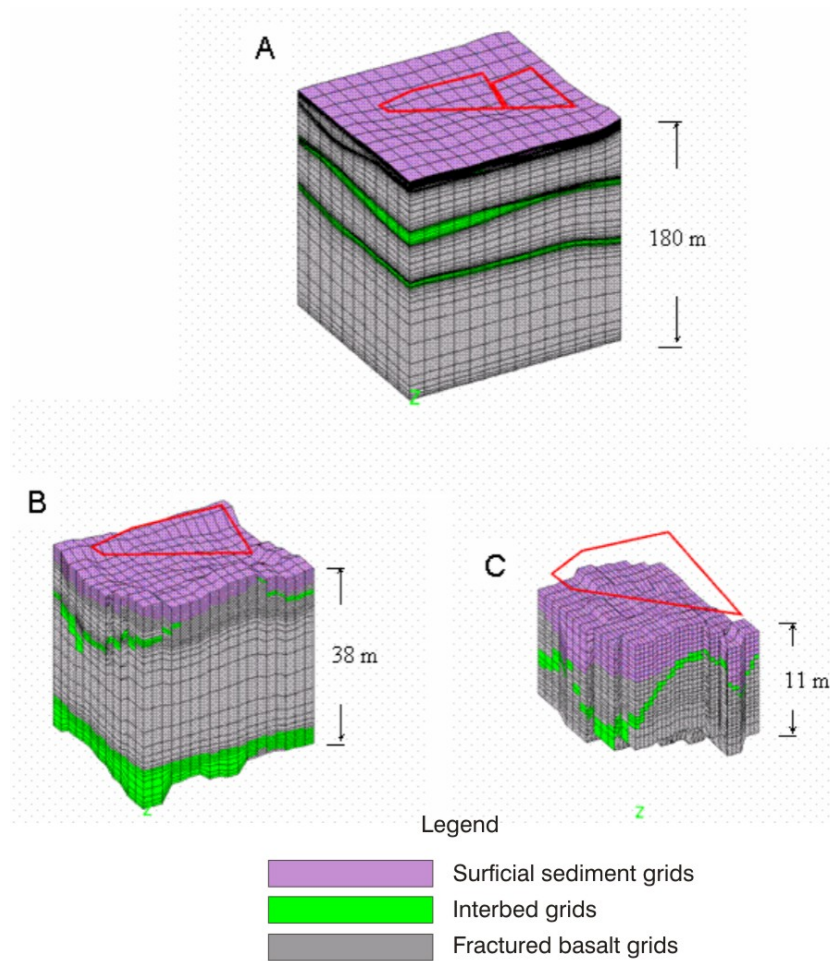


Figure E-6. Eighteen source areas simulated in the source-release model.



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Figure E-7. Southwest views of base grid (A), first-level refined grid (B), and second-level refined grid (C) beneath the Subsurface Disposal Area showing vertical conformable gridding. The A-B interbed appears black in the base grid as a result of fine vertical discretization.

preserving higher concentrations that reflect concentrations influxing from the vadose zone. Figure E-8 compares results from various sensitivity simulations for U-238 (a long-lived actinide), C-14 (a dual-phase radionuclide), and nitrate (a dissolved-phase nonradionuclide). Maximum concentrations anywhere in the aquifer are presented to facilitate comparison between various sensitivity simulations. The different simulations are identified using the following nomenclature:

- B = Baseline risk assessment
- Bli = Baseline risk assessment with low infiltration inside the SDA
- B4ng = Baseline risk assessment with no retrieval and no beryllium block grouting
- Bu = Baseline risk assessment with upper-bound inventory
- Bhi = Baseline risk assessment with high infiltration inside the SDA
- Bloi = Baseline risk assessment with low background infiltration outside the SDA
- Bnbc = Baseline risk assessment with no B-C interbed
- Bnlk = Baseline risk assessment with no low-permeability region.

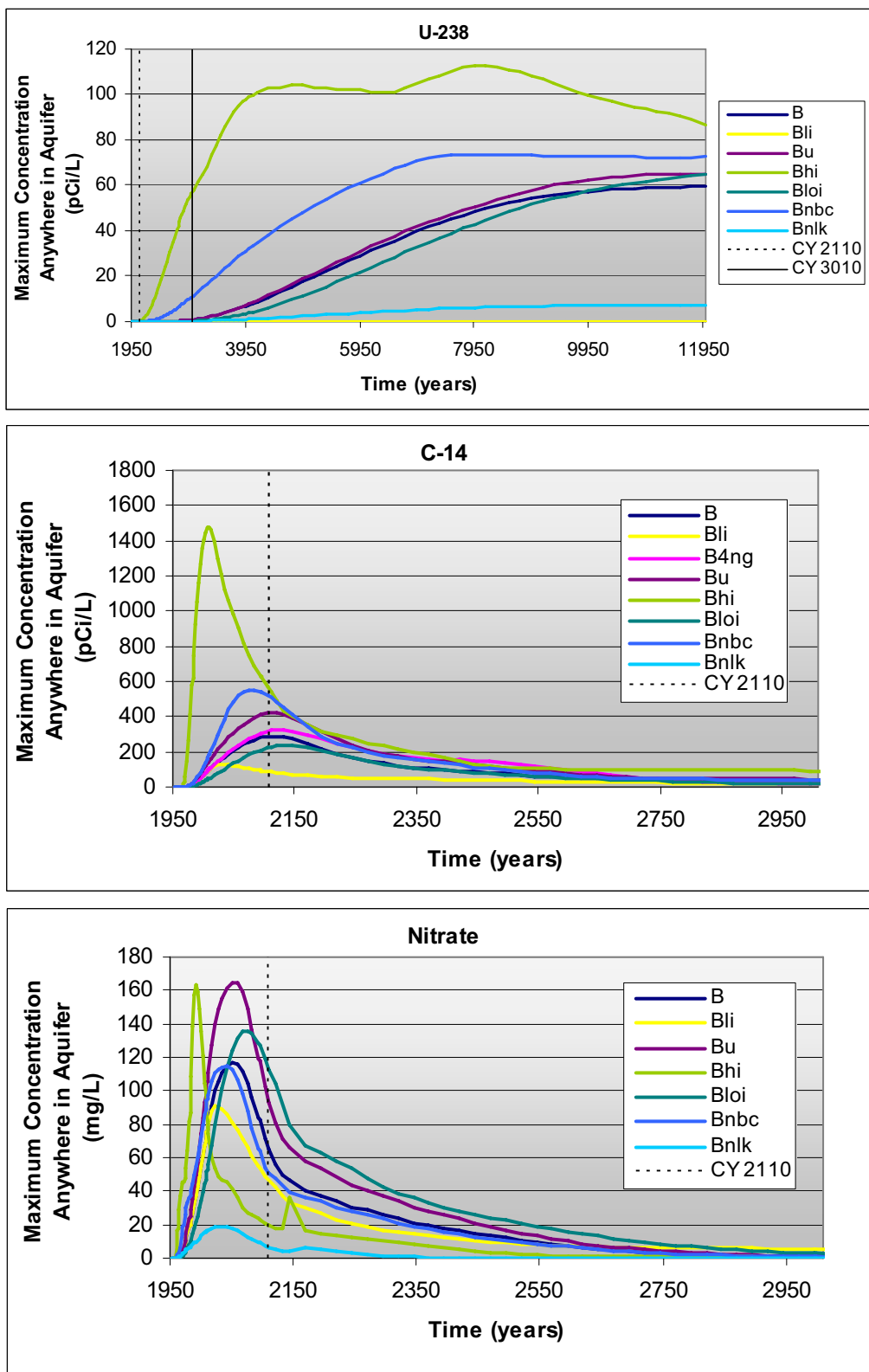


Figure E-8. Combined sensitivity results for maximum simulated concentration anywhere in the aquifer for uranium-238, carbon-14, and nitrate.

Best judgment was used to select parameters for the source-release model and the subsurface flow and transport model. Fortunately, from an environmental consequence perspective, movement of contaminants in the vadose zone and aquifer beneath the SDA is slow, and no extensive dissolved-phase contaminant plume is available against which to calibrate. An extensive database exists for contaminants in the waste zone, unsaturated zone, perched groundwater (when and where present), and regional aquifer, but there is no clear general pattern of contaminant detections nor trends in concentrations at this time, except for the volatile contaminants. Results of source-release and dissolved-phase subsurface flow and transport models can be compared only to the presence or absence of contaminants in field monitoring data instead of calibration to a contaminant plume. The ongoing monitoring program and evaluation of monitoring results are time consuming and expensive. Results of these monitoring activities have shown promise in identifying trends in contaminant behavior that are useful for determining the relative conservatism in modeling.

Limited calibration to vapor-phase carbon tetrachloride was achieved. Particular parameters were adjusted within reasonable uncertainty ranges until model results adequately agreed with observations of carbon tetrachloride in vadose zone soil-gas and aqueous concentrations in the aquifer. The goal of calibration was to match observed general trends and not be overly concerned with matching values at specific points. This goal was achieved. Limited calibration also was achieved in representing spatial distribution of observed soil-water matric potentials in the B-C and C-D interbeds, where wetter conditions are consistently observed within SDA boundaries compared to locations outside the SDA fence.

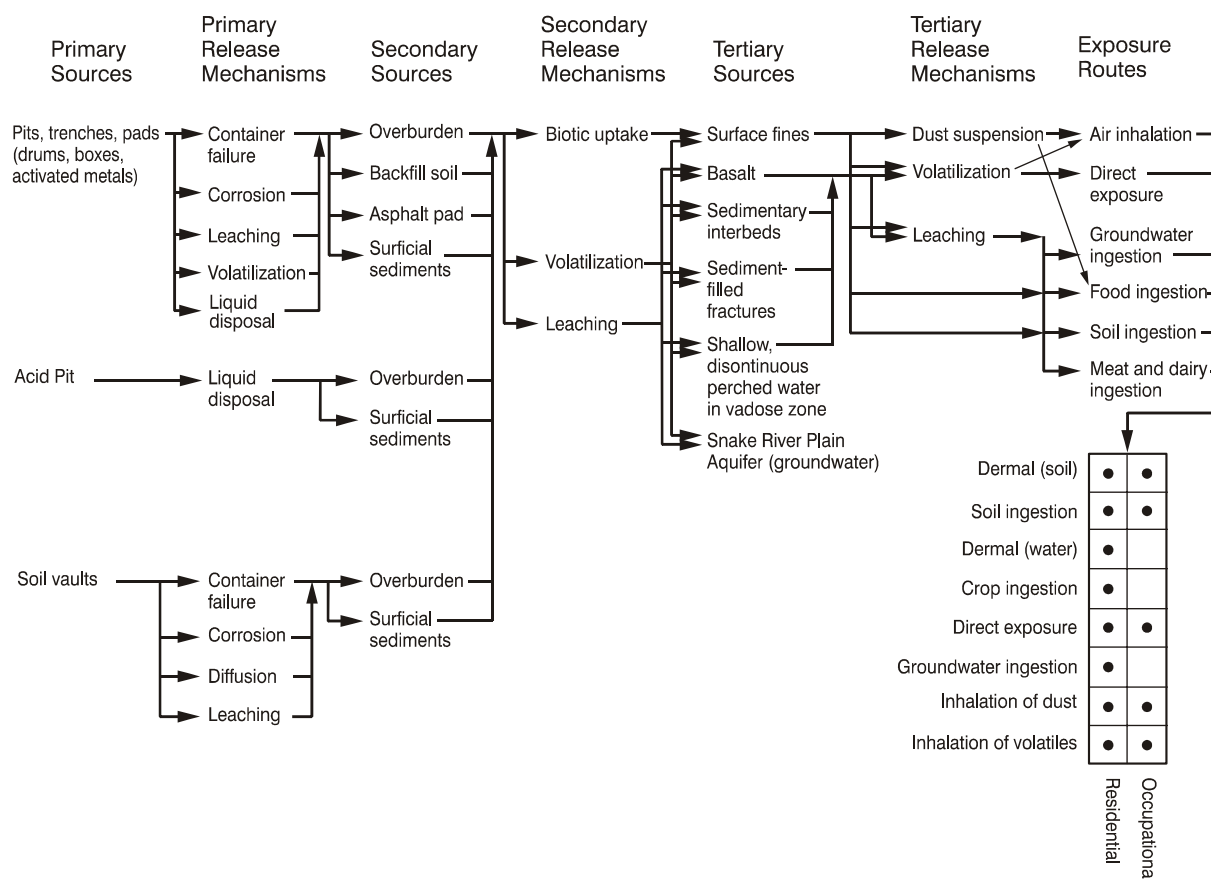
Personnel from DOE, DEQ, and EPA consider model results a reasonable basis for estimating potential risk to human health and the environment and for assessing appropriate remedial alternatives to mitigate unacceptable risk. However, results must be considered in light of uncertainties associated with this analysis. Modeling results (i.e., simulated concentrations) are consistently overpredicted in the aquifer (i.e., neglecting sporadic detections), overpredicted at some vadose zone monitoring locations, and underpredicted at other vadose zone monitoring locations. In general, groundwater pathway modeling results are conservative. This conservatism primarily results from (1) overestimating contaminant source release, (2) including rapid vertical transport in the fractured basalt portions of the vadose zone, and (3) including the extensive low-permeability region in the aquifer domain, which limits dilution. Because the model overpredicts current concentrations in the aquifer, it is certain that model results are conservative at present. The amount of uncertainty in the predictive results undoubtedly increases with time, decreasing the level of confidence that the model remains reasonably conservative over time. Monitoring over time and comparing monitoring results against model predictions will be an important aspect of post-record of decision monitoring.

E-1.1.6 Summary of Section 6—Baseline Risk Assessment

Human health and ecological risk assessments in Section 6 are based on simulated concentrations of contaminants in environmental media developed through numerical modeling (see Section E-1.1.5). Potential threats to human health and the environment, in the absence of any remedial action, are evaluated. The following subsections provide a synopsis of general approaches and results of human health and ecological risk assessments.

E-1.1.6.1 Human Health Baseline Risk Assessment. Building on earlier results in the IRA and the ABRA, Section 6 addresses potential risk to human health from contaminants buried in the SDA. Based on EPA and INL guidance (EPA 1988, 1989; Burns 1995), Waste Area Group 7 was comprehensively assessed by evaluating cumulative, simultaneous risk for all complete exposure pathways for all contaminants of potential concern. The risk assessment included exposure and toxicity assessments, risk characterization, parametric sensitivity analysis, and qualitative evaluation of

uncertainty. Contaminant screening for the RI/BRA identified 33 human health contaminants of potential concern for quantitative evaluation: 27 radionuclides, five VOCs, and one inorganic chemical. Risk estimates were developed for occupational and residential scenarios for complete exposure pathways identified in the conceptual site model (see Figure E-9).



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Figure E-9. Human health conceptual site model.

E-1.1.6.1.1 Occupational Scenarios—Evaluation of a current occupational scenario yielded risk estimates exceeding $1\text{E-}06$; therefore, future occupational risks also were assessed as required in the Second Addendum (Holdren and Broomfield 2004). Risk estimates exceed $1\text{E-}06$ for Sr-90 and carbon tetrachloride for the current occupational scenario. However, risk reaches maximum values for both contaminants within the 100-year current occupational scenario timeframe; therefore, though the future occupational scenario was assessed, results do not add important conclusions to risk characterization.

E-1.1.6.1.2 Residential Scenarios—For the current residential scenario, groundwater ingestion risk at the nearest downgradient INL Site boundary was assessed. Surface exposure pathways were not examined for a current residential exposure because residential development near RWMC is prohibited by site access restrictions. Cumulative risk for the current residential scenario is approximately $1\text{E-}06$.

Future residential exposures were simulated, beginning in the year 2110, following an assumed 100-year institutional control period. Future residential analysis reflects land-use projections and the assumption that institutional controls would preclude direct access into the waste, but that a location immediately adjacent to RWMC could be inhabited. The future residential scenario bounds the risk, meaning that risk estimates are higher than for all other exposure scenarios. Concentrations and risks were simulated out to 1,000 years for all pathways except groundwater ingestion. Groundwater risks were simulated until concentrations peaked or to a maximum of 10,000 years.

For residential scenarios, 18 contaminants within the 1,000-year simulation period have cumulative risk greater than or equal to $1\text{E-}05$, a hazard index greater than or equal to 1, or simulated groundwater concentrations that exceed MCLs. Residential risk estimates are greater than or equal to $1\text{E-}05$, or simulated groundwater concentrations are greater than MCLs for eight additional contaminants within the 10,000-year simulation period.

In the 1,000-year simulation period, highest residential risks are driven by biotic uptake and surface pathway exposure from Am-241, Cs-137, Pb-210, Pu-239, Pu-240, Ra-226, Ra-228, Sr-90, Th-228, and trichloroethylene. Risks from I-129, 1,4-dioxane, and nitrate are primarily through groundwater pathway exposures; risks from C-14 and carbon tetrachloride are primarily through groundwater and vapor inhalation (at the surface) exposures, while Tc-99 risk is primarily through groundwater ingestion and irrigating crops with groundwater. Simulated groundwater concentrations for the 1,000-year simulation period exceed MCLs immediately adjacent to the SDA for I-129, Tc-99, carbon tetrachloride, 1,4-dioxane, methylene chloride, nitrate, tetrachloroethylene, and trichloroethylene.

Figure E-10 shows total risk over time and relative contributions attributable to each exposure pathway for the future residential scenario immediately adjacent to the SDA. Except for inhalation of volatiles, risk remains greater than $1\text{E-}05$ for each exposure pathway throughout the 1,000-year simulation period, and cumulative risk remains well above $1\text{E-}03$. External exposure and soil ingestion dominate the risk. Crop ingestion risk is initially higher than soil ingestion risk immediately after institutional control. Inhalation risk is less than $1\text{E-}05$ immediately after institutional control but increases rapidly. Volatile inhalation risk is slightly greater than $1\text{E-}05$ at the end of institutional control but decreases to less than $1\text{E-}05$ within 50 years. Figures E-11 through E-15 illustrate individual pathway risks for surface exposure pathways over 1,000 years. Each figure shows the total by pathway, major contributors to the total, and the sum of other contaminants.

Figure E-16 shows total 1,000-year groundwater ingestion risk for all radionuclides and nonradionuclides, major contributors to the total, and the sum of other contaminants. Groundwater ingestion risk immediately after the end of institutional control is driven by carbon tetrachloride and Tc-99. Within the 1,000-year simulation, eight contaminants exceed their respective MCLs: I-129, Tc-99, carbon tetrachloride, 1,4-dioxane, methylene chloride, nitrate, tetrachloroethylene, and trichloroethylene. Results for Tc-99 and I-129, particularly for groundwater exposure pathways, are highly uncertain because simulated concentrations in the vadose zone and aquifer are grossly inconsistent with monitoring data. As a consequence, groundwater risk attributable to these contaminants could be significantly misrepresented. For example, if actual release is very slow, initial risk (i.e., in the year 2110) would be substantially lower, perhaps less than $1\text{E-}05$. Risk from slower release also would be incurred over a longer period. Conversely, the current simulations imply that risk is very high early in the simulation timeframe and diminishes over a few hundred years.

Groundwater simulations were extended to 10,000 years to evaluate long-lived radionuclides that did not achieve peak simulated concentrations in the 1,000-year simulations. Estimated risk is greater than or equal to $1\text{E-}05$ for eight actinides: Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. Primary contributors are Np-237 and U-238. Concentrations exceed MCLs in the 10,000-year simulations for these same two actinides.

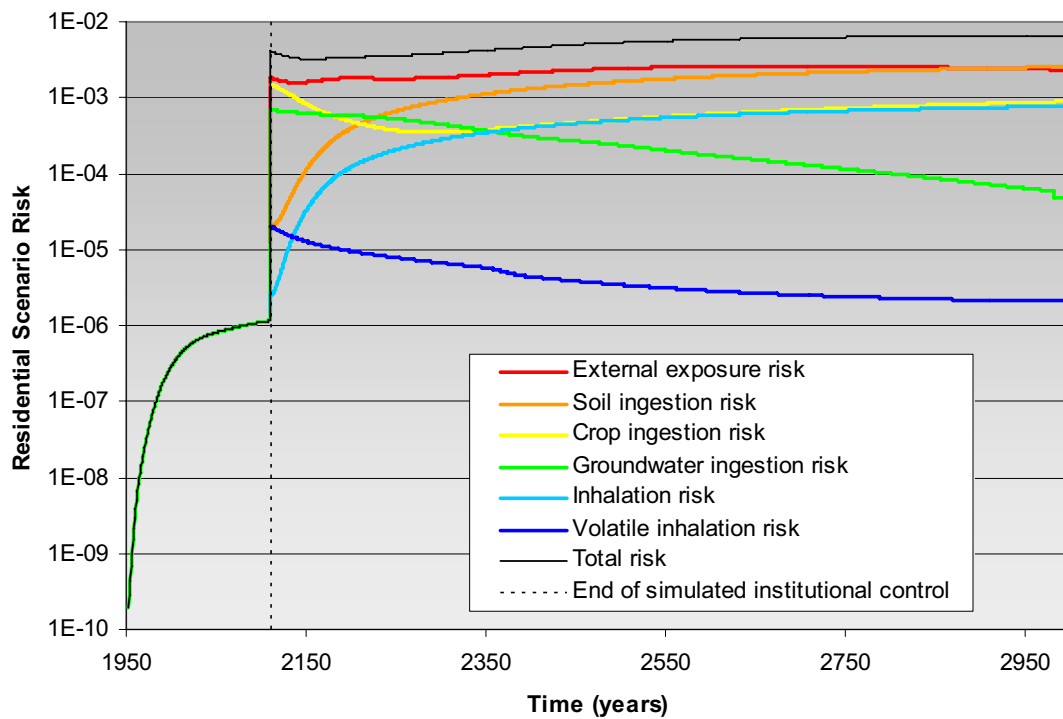


Figure E-10. Total residential exposure scenario risk by exposure pathway for all radionuclides and nonradionuclides.

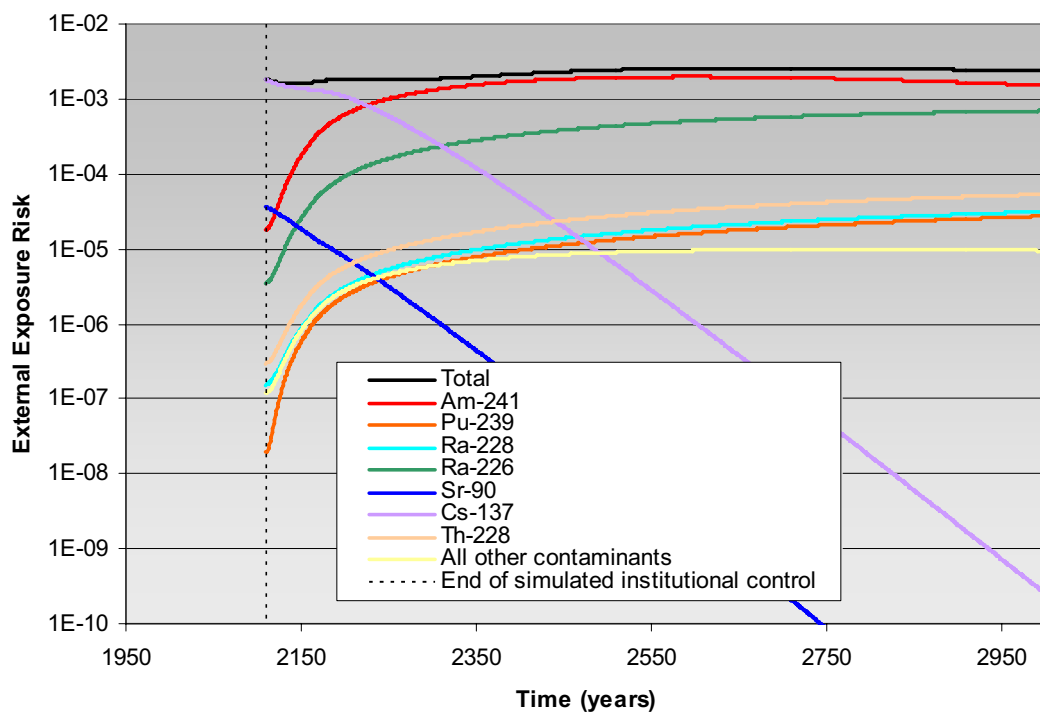


Figure E-11. Major contributors to external exposure risk.

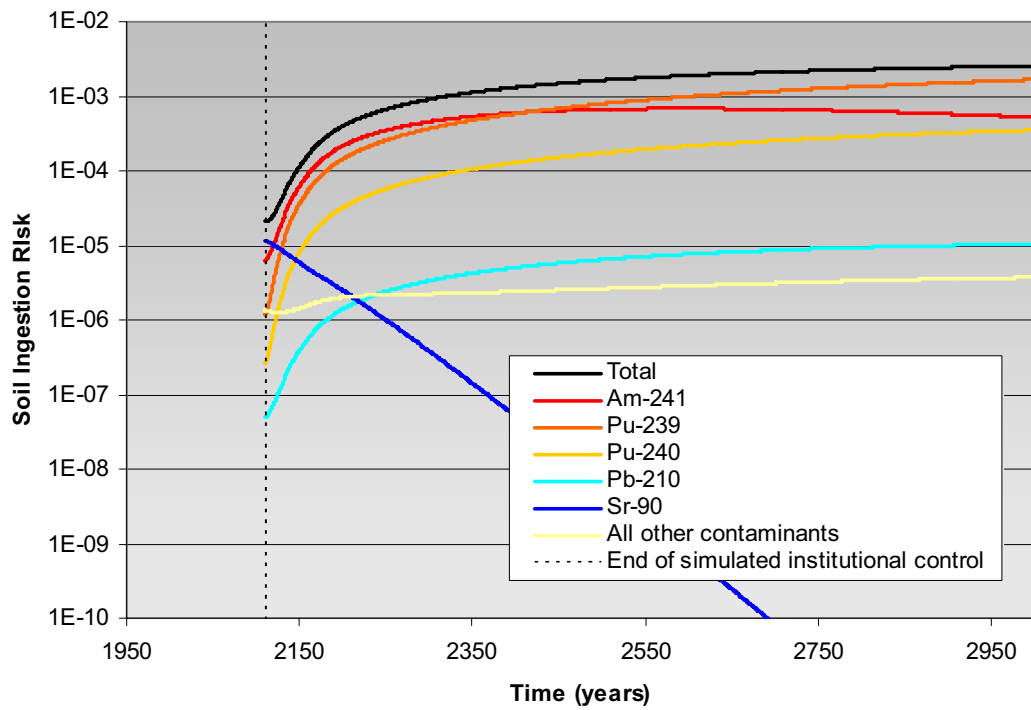


Figure E-12. Major contributors to soil ingestion risk.

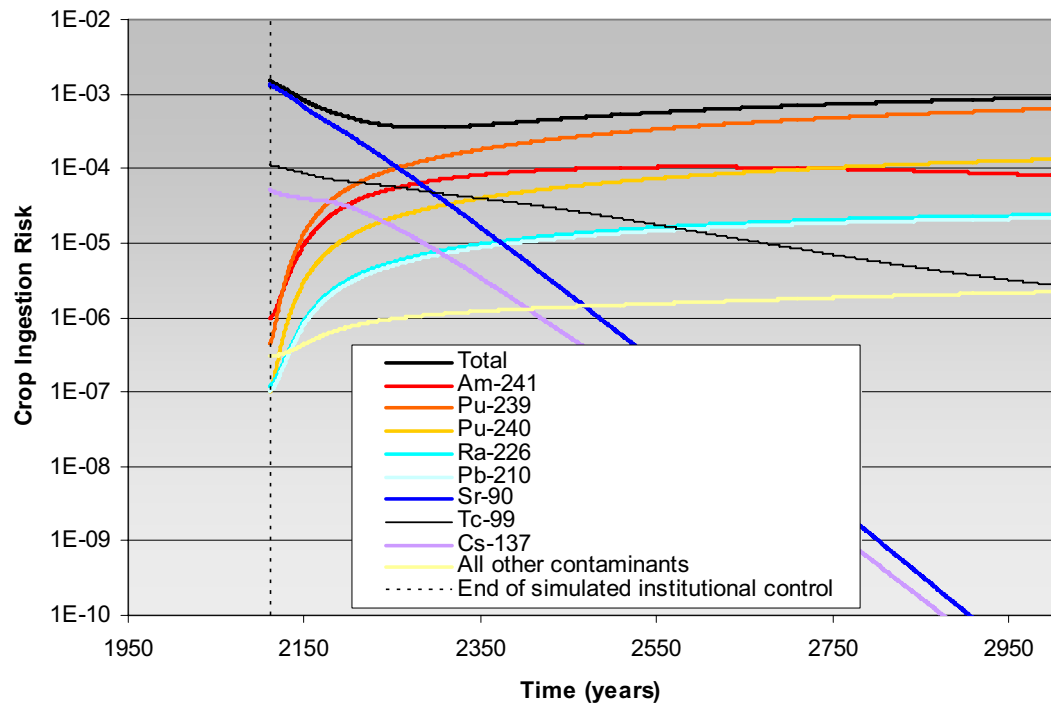


Figure E-13. Major contributors to crop ingestion risk.

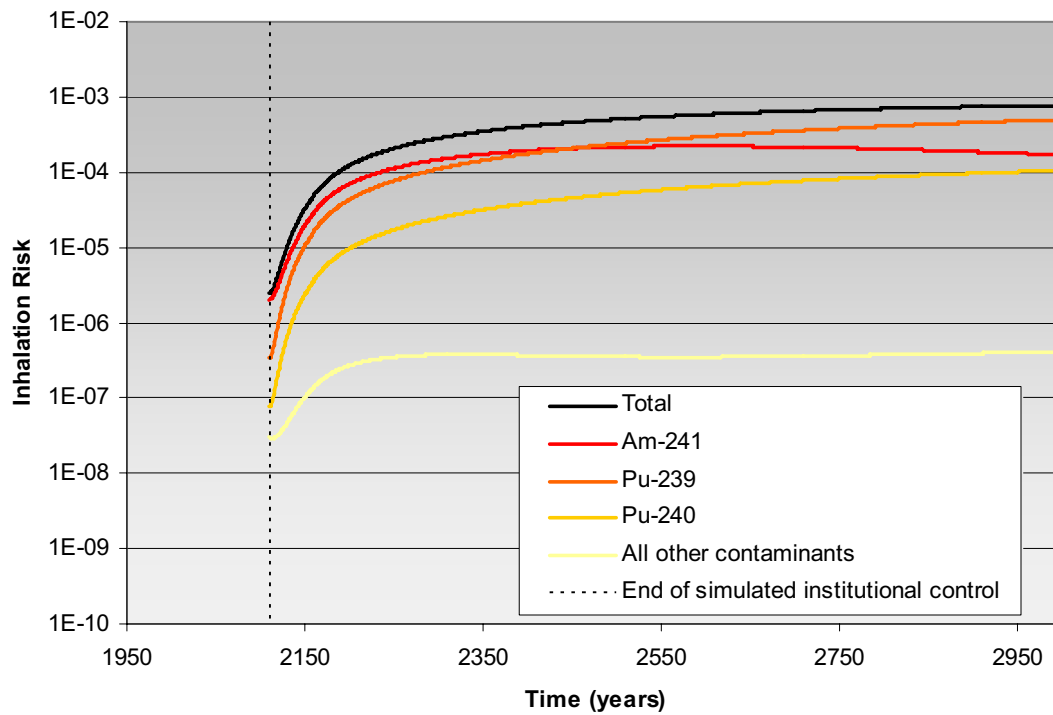


Figure E-14. Major contributors to inhalation risk.

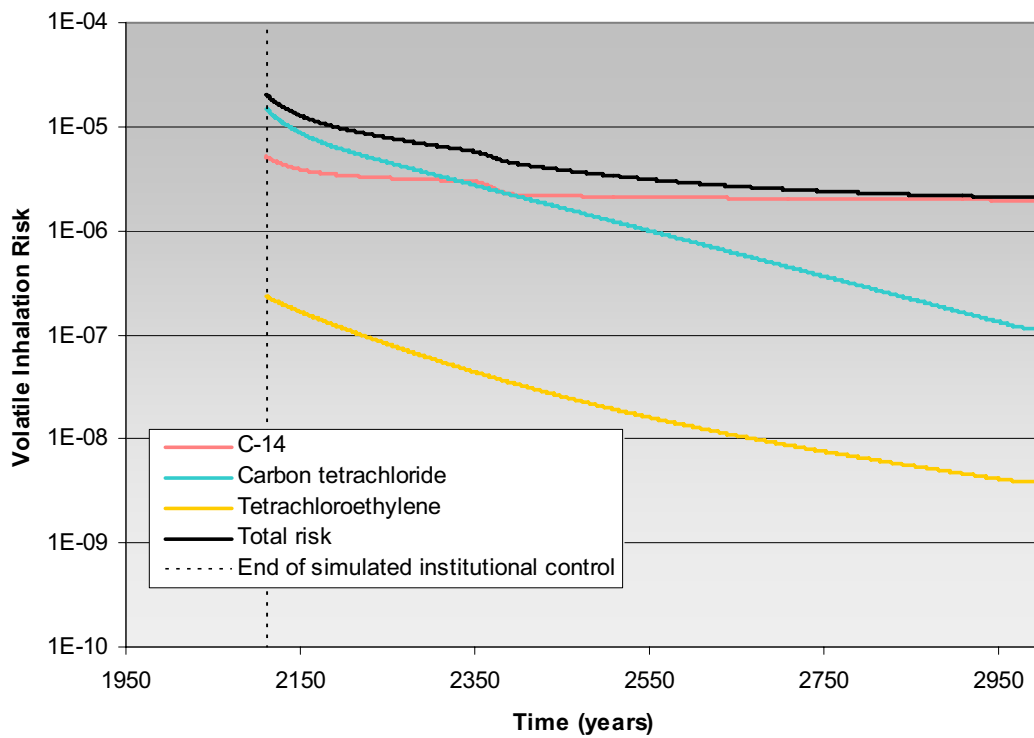


Figure E-15. Volatile inhalation risk by contaminant.

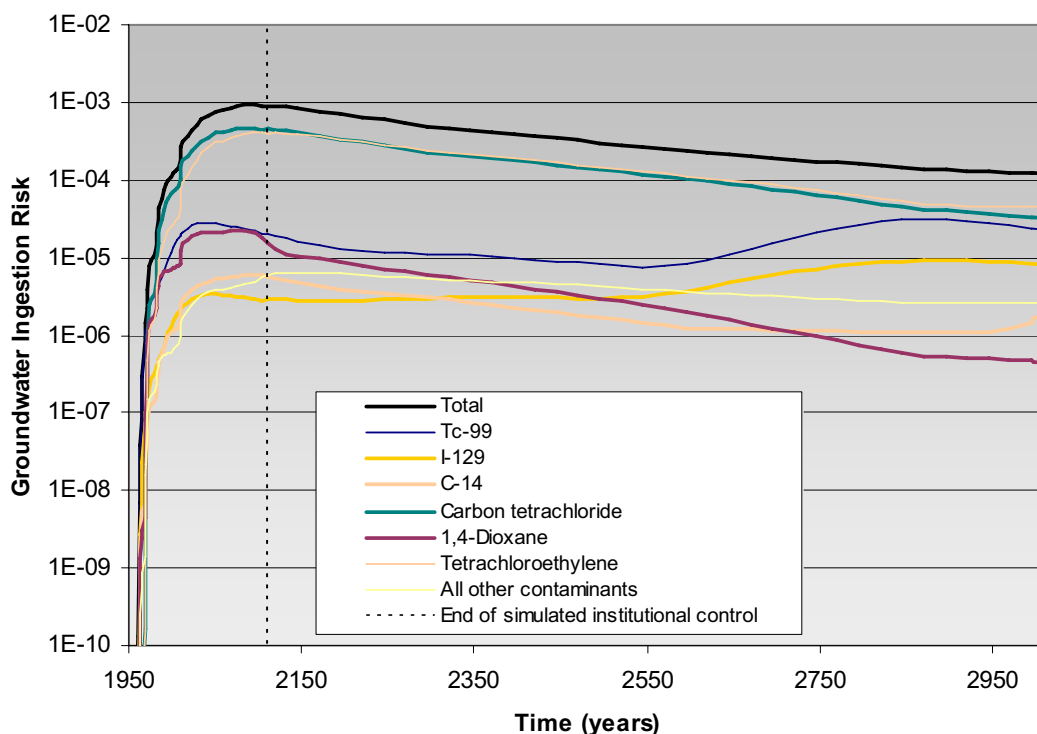


Figure E-16. Groundwater ingestion risk by contaminant.

E-1.1.6.1.3 Uncertainty—Parametric sensitivity and qualitative uncertainty analyses were performed for parameters identified by DOE, DEQ, and EPA as important for understanding uncertainty in base-case risk. The sensitivity analysis shows the effect on predicted risk of changes in selected model inputs. With the exception of inventory sensitivity, sensitivity analysis focused on the groundwater ingestion pathway. The following list summarizes sensitivity cases:

- **Inventory**—To assess sensitivity to source-term inventory, risk was estimated based on upper-bound inventories. Risk estimates for most contaminants were of the same order of magnitude, with total cumulative risk for all contaminants higher by an approximate factor of 2.
- **Infiltration**—Three sensitivity cases addressing infiltration rates were examined: (1) reduced background infiltration outside the SDA, (2) low infiltration inside the SDA, and (3) high uniform infiltration inside the SDA. Reduced background infiltration produced slightly higher risk estimates, while lower and higher infiltration inside the SDA paralleled lower and higher risk.
- **Interbed gaps**—The effect of neglecting known gaps in the B-C interbed was evaluated by completely eliminating the B-C interbed in the model; negligible effect was noted.
- **Pit 4 retrieval and beryllium block grouting**—Because the base case incorporated assumptions that beryllium blocks would be grouted and targeted retrieval in Pit 4 would be completed, a sensitivity case was performed to examine consequences of not completing these remedial actions. If beryllium blocks are not grouted, C-14 groundwater ingestion risk increases slightly. If the half-acre retrieval in Pit 4 is not completed, groundwater risk does not change. Except for carbon tetrachloride, Rocky Flats Plant contaminants do not drive groundwater risk. The retrieval area contains only a small fraction of the carbon tetrachloride.

- **Low-permeability zone**—Effects of the postulated low-permeability zone assumed for the base case were evaluated by implementing a sensitivity case that did not include such a region in the aquifer. In the absence of a low-permeability zone, risk estimates are substantially lower (e.g., decrease from 3E-04 to 4E-05 for radionuclides, excluding Tc-99 and I-129), further suggesting that base-case model results are conservative.
- **No sorption in interbeds**—Removing the effects of plutonium sorption in interbed sediment was evaluated by completely eliminating sorption in the B-C and C-D interbeds using an approach roughly equivalent to spreading the plutonium source term into a thin layer (i.e., by advective spreading in the vadose zone) and leaching it directly into the aquifer. Results of this extremely conservative simulation show several orders of magnitude increase in risk.

E-1.1.6.2 Inadvertent Intruder Analysis. The intrusion scenario in Section 6.6 evaluates acute risk to a hypothetical worker drilling an agricultural irrigation well after the institutional control period. Two locations in the SDA (i.e., a high-gamma area and a high-alpha area) were selected for evaluation, based on disposal records. Results show that the high-gamma location could pose a risk of 4E-04, largely from external exposure to Cs-137. For the high-alpha location, the total risk is 4E-07.

E-1.1.6.3 Ecological Risk Assessment. The ecological risk assessment in Section 6.7 was a screening-level analysis because of the fundamental assumption that the SDA will be covered with a surface barrier (DOE-ID 1998; Holdren and Broomfield 2004). Current and 100-year scenarios were evaluated for representative receptors. Contaminant screening focused evaluation on those contaminants most likely to pose unacceptable risk; 56 contaminants of potential concern were identified—16 radionuclides and 40 nonradionuclides. Concentrations in surface soil and subsurface intervals were estimated with the DOSTOMAN biotic uptake model. Receptor exposures were evaluated for all 16 Waste Area Group 7 radionuclides; eight of the 40 nonradionuclides were evaluated as indicators of potential risk. Thirteen contaminants, ten radionuclides (i.e., Am-241, Cs-137, Pu-238, Pu-239, Pu-240, Pu-241, Ra-226, Sr-90, U-234, and U-238), and three nonradionuclides (i.e., beryllium, cadmium, and lead) were shown to pose risk greater than threshold values to Waste Area Group 7 ecological receptors in both the current and future scenarios.

E-1.2 Conclusions of the Remedial Investigation and Baseline Risk Assessment

Conclusions based on this RI/BRA provide the foundation for subsequent analysis and ultimately will support risk management decisions for Operable Unit 7-13/14. The first subsection below reviews the approach applied by DOE, DEQ, and EPA to address uncertainties inherent in this RI/BRA. Results of the risk assessment and uncertainty associated with those results then are used to transition from the RI/BRA to the feasibility study. Contaminants of *potential* concern (i.e., those contaminants that *might* pose unacceptable risk if no remediation is implemented) are screened to identify contaminants of concern (COCs) (i.e., those contaminants that might require risk management decisions). Final subsections present recommendations for the feasibility study and reiterate remedial action objectives.

E-1.2.1 Basis for Conclusions—Overall Uncertainty in Modeling and Risk Assessment

Personnel from DOE, DEQ, and EPA have actively participated throughout development of the RI/BRA to produce a mathematical modeling approach useful for predicting release and transport of contaminants from waste buried in the SDA. The unchanging goal has been to develop a reasonably conservative model—one that is not excessively conservative (overpredicting concentrations) or excessively nonconservative (underpredicting concentrations). This is a difficult goal to achieve in any simulation, but even more difficult for Operable Unit 7-13/14 for several reasons, as described in the following subsections.

E-1.2.1.1 Inventory. The SDA is a landfill that has received thousands of shipments over the past five decades. Thousands of records have been researched extensively to verify source-term information for the SDA. Data have been compiled into a database that can query shipments. Though some shipment locations have been verified through probing into a few key areas, absolute certainty is not a practical objective for a 97-acre landfill (containing approximately 35 acres of waste) that has been in service since 1952. However, the database includes inventory estimates (mass or curies), an approximate location, and waste form descriptions for almost every shipment placed in the SDA. This information is used to fulfill modeling requirements for site characterization data. For instance, modeling requires information about inventories of contaminants and the physical form of the waste. Information must be developed to address the following: whether contaminants are in solution, whether they are sorbed into a matrix in bags inside barrels, whether barrels are carbon steel or stainless steel, whether waste is in boxes and whether boxes are wood or cardboard, and how contaminants release from waste and how fast.

E-1.2.1.2 Infiltration. Movement of dissolved-phase (aqueous) contaminants in the unsaturated zone is controlled by the amount of water moving through the sedimentary layers. Typically, contaminants are transported in the shallow vadose zone in pulses that correlate with precipitation. These pulses are not specifically modeled. This compromise in the temporal effects of water movement causes some uncertainty in the modeling but was acceptable to DOE, DEQ, and EPA because pulses generally dampen with depth and do not influence long-term simulation results at depth. Water movement through sedimentary features can be described by a nonlinear set of equations, which are computer intensive to solve because the hydraulic conductivity of the layers depends on the moisture content and other characteristics of the materials in the layer. Complexity of variably saturated water movement through fractured basalts is less well understood, but significant insight into this movement and confidence in the equivalent-porous continuum modeling approach was gained by successful inverse modeling of a large-scale infiltration test that was conducted near RWMC in support of the RI/FS.

E-1.2.1.3 Sorption. Transport in the vadose zone and aquifer also is controlled by the tendency of each contaminant to adsorb onto sedimentary interbeds and, to a much lesser degree, to fractures in basalt. These contaminants can exist in different forms (e.g., oxidation states) in the environment, which greatly affects sorption. Mineralogy of sedimentary interbeds varies laterally and vertically within each sedimentary feature. An attempt to characterize spatial variability using distribution coefficients measured on corehole samples was unsuccessful in identifying spatial correlation. Therefore, single average values must be used to represent sorption for each contaminant, increasing the uncertainty in modeling results. Site-specific values were applied for sediments, when available; otherwise, conservative values were selected. Sorption of contaminants conservatively was assumed to not occur with fractured basalts.

E-1.2.1.4 Calibration. Modeling efforts at the other INL Site facilities (e.g., Test Area North and Idaho Nuclear Technology and Engineering Center) were facilitated by the presence of contaminants in soil, perched water, or the aquifer from past releases. Characterization data describing spatial and temporal aspects of these releases and presence of plumes within the aquifer provided benchmarks for model development. Fate and transport models could be reasonably calibrated to these plumes. A similar

approach could not be implemented for Operable Unit 7-13/14 because well-defined plumes, patterns of detection, and consistent trends in concentrations do not exist, except for VOCs. Simulations for dissolved-phase contaminants, therefore, can be compared only to the absence or presence of contaminants in monitoring. The model sometimes predicts the presence of contaminants in the unsaturated zone or in the regional aquifer when those contaminants have not been detected. This modeling effort, except for calibrated VOC modeling, is wholly predictive.

E-1.2.1.5 Simulation Periods. Because this modeling effort is wholly predictive (except for VOCs), the predictive nature of the modeling for 100-year timeframes (i.e., restoration timeframe) is uncertain, and the degree of uncertainty is much greater for the longer 1,000-year timeframes. This uncertainty was recognized and accepted by DOE, DEQ, and EPA in the context of developing risk management decisions for Operable Unit 7-13/14. Extending groundwater simulations to 10,000 years was identified as necessary to assess potential long-term risk to human health and the environment because of the long-term presence and slow movement of some contaminants of concern. However, the level of uncertainty for these predictions is very large. These modeling predictions and the relative degree of uncertainty will be considered by DOE, DEQ, and EPA in developing risk management decisions.

E-1.2.2 Contaminants of Concern

Contaminants of concern are identified by reviewing human health risk estimates and simulated groundwater concentrations for contaminants of potential concern and applying screening criteria. Contaminants of concern are those individual contaminants that, when combined, cause cumulative risk to exceed threshold values. The EPA established a risk range from 10^{-4} to 10^{-6} for managing risk and expresses preference for the more protective end of the range (EPA 1991). The presence of multiple contaminants and exposure pathways (EPA 1989), land use projections (EPA 1995), and guidelines for risk management decisions (EPA 1997) also are important considerations in identifying COCs. Carcinogenic risk of $1\text{E-}04$ and a hazard index of 1 for a future residential scenario are typical human health threshold values applied by DOE, DEQ, and EPA to support risk management decisions at the INL Site. Contaminants of concern then become the focus of an evaluation of remedial alternatives (i.e., a feasibility study) and, ultimately, risk management decisions.

Primary COCs for Operable Unit 7-13/14 are identified based on either of two screening criteria:

1. Contaminant has a total carcinogenic risk estimate greater than or equal to $1\text{E-}05$ or a hazard index greater than or equal to 1 within the 1,000-year simulation period for the future residential exposure scenario. (The value of $1\text{E-}05$ is used to identify COCs to ensure that additive carcinogenic risk from multiple contaminants remains less than the threshold of $1\text{E-}04$.)
2. Simulated groundwater concentrations exceed the EPA MCLs within the 1,000-year simulation period.

Tables E-1 and E-2 identify radionuclide and nonradionuclide COCs, respectively, based on the above criteria. In total, 18 primary COCs are identified: 12 radionuclides and six nonradionuclides. Cumulative risk over time for all COCs is illustrated in Figure E-10 for the future residential scenario. Total cumulative risk for all contaminants is at a maximum of $7\text{E-}03$ at the end of the 1,000-year simulation period in the year 3010. Surface exposure pathways contribute the most risk throughout the 1,000-year simulation period, with a maximum of $7\text{E-}03$. As shown in Figures E-11 through E-15, the most significant contributors to surface pathway risk are Am-241, Cs-137, Pu-239, Sr-90, and carbon tetrachloride.

Table E-1. Primary radionuclide contaminants of concern based on 1,000-year future residential scenario peak risk estimates and groundwater concentrations.

Radionuclide	Peak Risk	Year	Primary Exposure Pathways ^a	Peak Aquifer Concentration (pCi/L)	Year	Maximum Contaminant Level (pCi/L)
Ac-227	5E-07	3010	Groundwater ingestion	5.30E-02	3010	15 ^b
Am-241	3E-03	2594	External exposure, soil ingestion, inhalation, and crop ingestion	6.80E-08	3010	15 ^b
Am-243	1E-07	3010	External exposure	1.29E-09	3010	15 ^b
C-14	1E-05	2110	Groundwater ingestion and inhalation of volatiles (at the surface)	1.86E+02	2133	2,000
Cl-36	2E-06	2384	Groundwater ingestion and crop ingestion	2.12E+01	2395	700
Cs-137	2E-03	2110	External exposure and crop ingestion	NA	NA	NA
I-129	4E-05	2110	Groundwater ingestion	1.31E+01	2111 ^c	1
Nb-94	2E-06	3010	External exposure	NA	NA	NA
Np-237	7E-06	2647	External exposure	6.53E-02	3010	15 ^b
Pa-231	3E-07	3010	Groundwater ingestion	8.17E-02	3010	15 ^b
Pb-210	3E-05	3010	Crop ingestion	1.02E-05	3010	NR
Pu-238	1E-06	2262	Soil ingestion, crop ingestion, and inhalation	6.10E-19	2920	15 ^b
Pu-239	3E-03	3010	Soil ingestion, crop ingestion, and inhalation	5.19E-10	3010	15 ^b
Pu-240	6E-04	3010	Soil ingestion, crop ingestion, and inhalation	1.28E-10	3010	15 ^b
Ra-226	7E-04	3010	External exposure and crop ingestion	1.30E-05	3010	5
Ra-228	3E-05	3010	External exposure	1.97E-09	3010	5
Sr-90	1E-03	2110	Crop ingestion, external exposure, and soil ingestion	NA	NA	NA
Tc-99	3E-04	2110	Groundwater ingestion and crop ingestion (crops irrigated with contaminated groundwater)	2.71E+03	2111 ^c	900
Th-228	5E-05	3010	External exposure	NA	NA	NA
Th-229	4E-07	3010	Groundwater ingestion	2.64E-02	3010	15 ^b
Th-230	1E-08	3010	Crop ingestion, soil ingestion, and inhalation	3.01E-04	3010	15 ^b
Th-232	3E-07	3010	Crop ingestion	2.82E-09	3010	15 ^b
U-233	4E-06	3010	Groundwater ingestion	2.90E+00	3010	2.9E+04
U-234	6E-07	3010	Groundwater ingestion	3.97E-01	3010	1.87E+05
U-235	2E-07	2286	External exposure	1.19E-01	3010	6.49E+01
U-236	9E-07	3010	Groundwater ingestion	6.24E-01	3010	1.94E+03
U-238	1E-06	2285	External exposure	5.52E-01	3010	1.01E+01

a. All complete exposure pathways are assessed in the baseline risk assessment; those contributing most to risk are listed as primary exposure pathways. For COCs, all exposure pathways with risk greater than 1E-05 are listed from highest to lowest risk.

b. The limit is 15 pCi/L for total alpha (40 CFR 141).

c. Reported values are for the end of institutional control. The simulated peak occurs before the end of the 100-year institutional control period.

d. The limit is 3E-02 mg/L (30 µg/L) for total uranium. To compare concentrations of uranium isotopes, 3E-02 mg/L is converted to the equivalent activity for each isotope.

COC = contaminant of concern

MCL = maximum contaminant level

NR = not regulated

Surface exposure pathway COC	Groundwater pathway COC	COC for both surface exposure and groundwater pathways	COC based on potential to exceed MCL
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Table E-2. Nonradionuclide contaminants of concern based on 1,000-year future residential scenario peak risk estimates and groundwater concentrations.

Contaminant	Peak Risk	Year	Peak Hazard Index	Year	Primary Exposure Pathways ^a	Peak Aquifer Concentration (mg/L) ^b	Year	Maximum Contaminant Level (mg/L)
Carbon tetrachloride	5E-04	2110	1E+01	2116	Inhalation of volatiles (at the surface) and groundwater ingestion	3.07E-01	2133	5.00E-03
1,4-Dioxane	2E-05	2110	NA	NA	Groundwater ingestion	1.69E-01	2111	3.00E-03 ^b
Methylene chloride	5E-06	2244	3E-02	2244	Groundwater ingestion	5.85E-02	2245	5.00E-03
Nitrate	NA	NA	1E+00	2110	Groundwater ingestion	6.67E+01	2094 ^c	10
Tetrachloroethylene	7E-07	2110	3E-01	2133	Groundwater ingestion	6.64E-02	2145	5.00E-03
Trichloroethylene	9E-04 ^d	2110	NA	NA	Inhalation of volatiles (at the surface) and groundwater ingestion	3.80E-02 ^d	2130	5.00E-03

a. All complete exposure pathways are assessed in the baseline risk assessment; those contributing most to risk are listed as primary exposure pathways. For COCs all exposure pathways with risk greater than 1E-05 or a hazard index greater than or equal to 1 are listed from highest to lowest risk.

b. No MCL is given, but a health advisory level is provided for reference.

c. The simulated nitrate peak occurs before the end of the 100-year institutional control period.

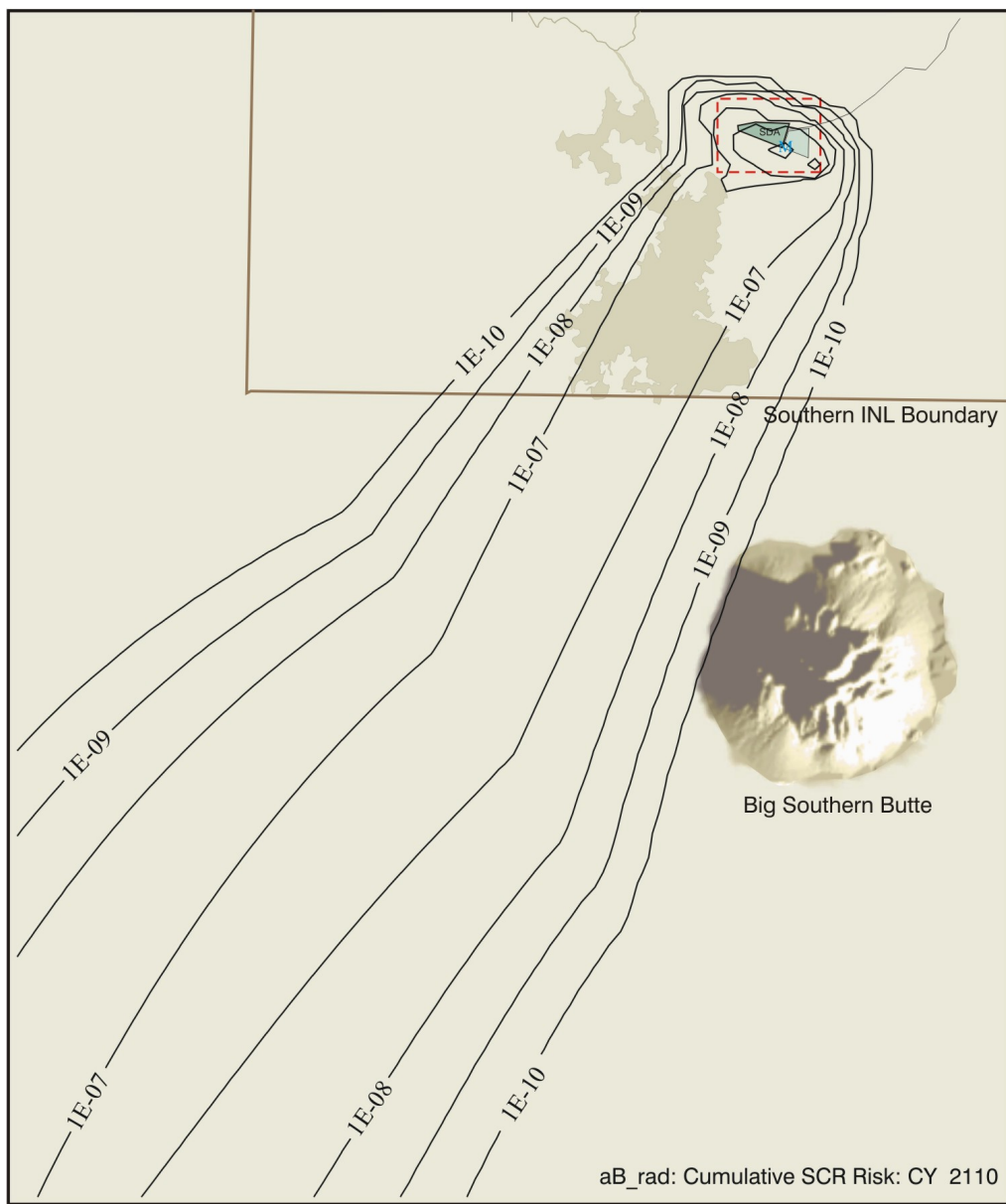
d. Trichloroethylene risk estimates and groundwater concentrations are based on scaling. Refined estimates will be developed in the feasibility study.

COC = contaminant of concern

MCL = maximum contaminant level

Surface exposure pathway COC	Groundwater pathway COC	COC for both surface exposure and groundwater pathways	COC based on potential to exceed MCL
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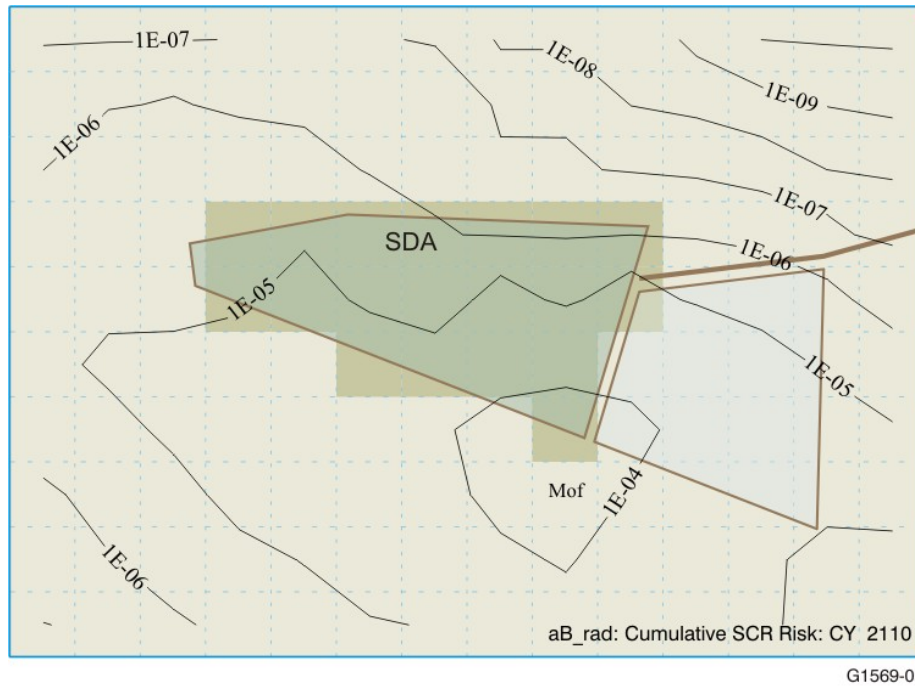
Cumulative groundwater ingestion risk within the 1,000-year simulation period reaches a peak of $7\text{E-}04$ at the end of the simulated institutional control period, when the location for the hypothetical residential receptor shifts from the INL Site boundary to the SDA boundary. Groundwater ingestion risk steadily diminishes over the 1,000-year simulation period (see Figure E-16). Cumulative groundwater ingestion risk isopleths are provided in Figures E-17, E-18, and E-19 for the 1,000-year residential scenario. In addition, groundwater ingestion hazard indexes of $1\text{E}+01$ and $1\text{E}+00$ are associated with carbon tetrachloride and nitrate, respectively. Maximum hazard index isopleths are shown in Figure E-20. Primary groundwater pathway risk drivers in the 1,000-year timeframe are carbon tetrachloride and Tc-99.



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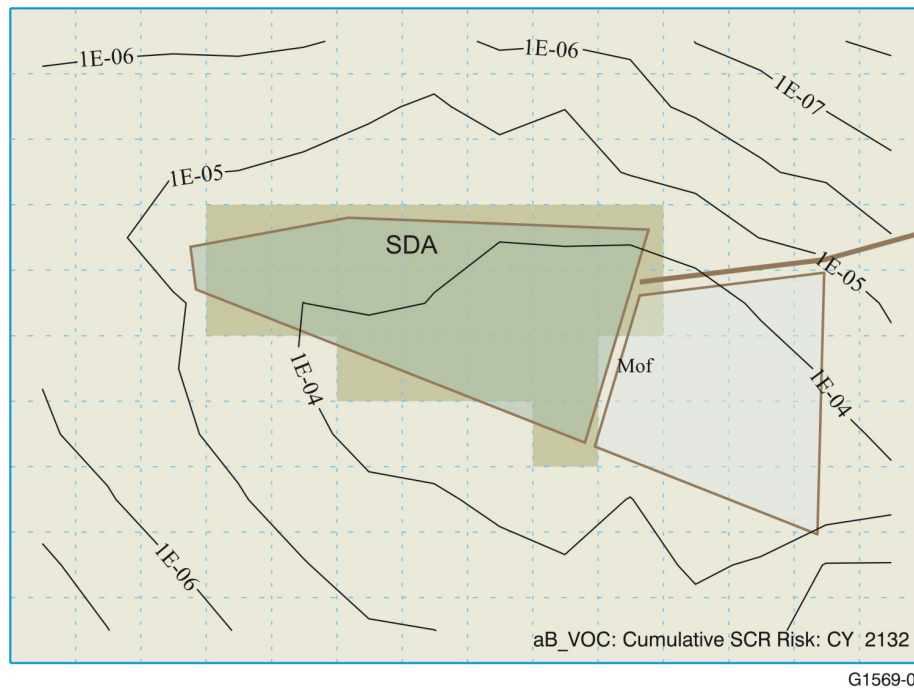
M = Maximum value = $2\text{E-}04$

Figure E-17. Peak cumulative groundwater ingestion risk isopleths for radionuclides for the regional refined grid.



Mof = Maximum value outside fence = 2E-04

Figure E-18. Peak cumulative groundwater ingestion risk isopleths for radionuclides for the refined aquifer grid.



Mof = Maximum value outside fence = 5E-04

Figure E-19. Peak cumulative groundwater ingestion risk isopleths for volatile organic compounds.

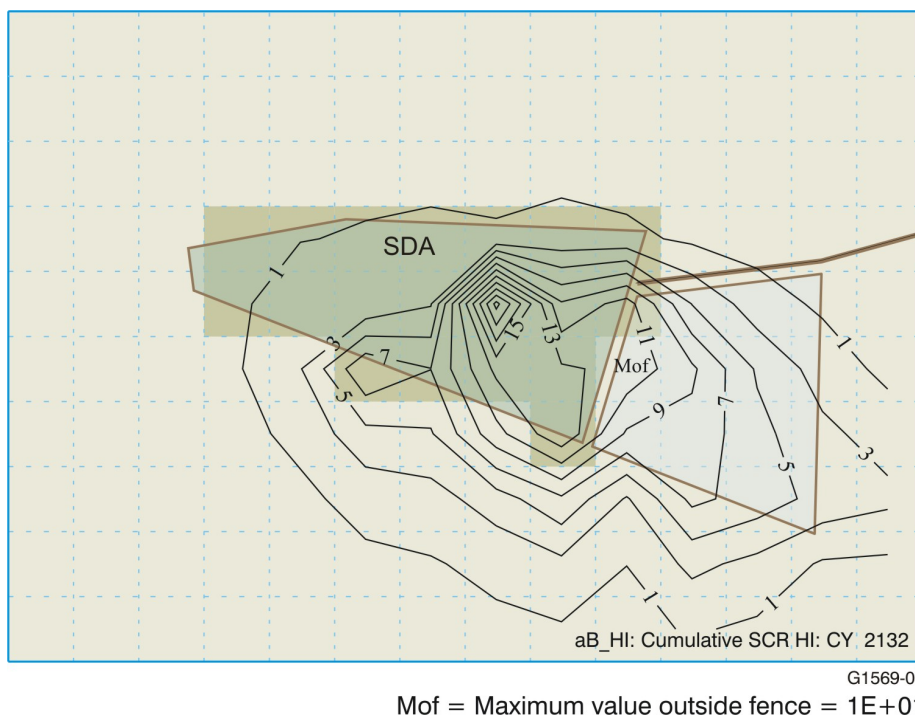


Figure E-20. Peak cumulative groundwater ingestion hazard index isopleths.

Risk estimates for Tc-99 and I-129 are highly uncertain because of gross inconsistencies between simulated and detected concentrations. Risks for Tc-99 and I-129 are likely overestimated, perhaps substantially. Figure E-21 shows groundwater ingestion risk with and without Tc-99 and I-129, illustrating upper-bound (represented by overestimated base case results) and lower-bound groundwater ingestion risk (represented by completely excluding Tc-99 and I-129). Actual risk is somewhere between these two extremes for Tc-99 and I-129. For comparison to Figure E-18, Figure E-22 shows groundwater risk isopleths without Tc-99 and I-129.

Simulated groundwater concentrations exceed MCLs (EPA 2000) within the 1,000-year simulation period for eight contaminants: two radionuclides and six nonradionuclides. Both radionuclides (i.e., I-129 and Tc-99) and four of the nonradionuclides (i.e., carbon tetrachloride, 1,4-dioxane, nitrate, and trichloroethylene) are identified as COCs because they exceed risk thresholds. Two additional COCs, methylene chloride and tetrachloroethylene, are identified solely on their potential to exceed their respective MCLs.

In total, 18 primary COCs are identified based on human health risk estimates or potential to exceed MCLs in the aquifer. Table E-3 identifies waste streams associated with these primary COCs. Several COCs (i.e., Pb-210, Ra-226, Ra-228, and Th-228) have very small initial inventories generated at the INL Site; however, risk is driven by inventories generated through ingrowth attributable to Rocky Flats Plant waste streams.

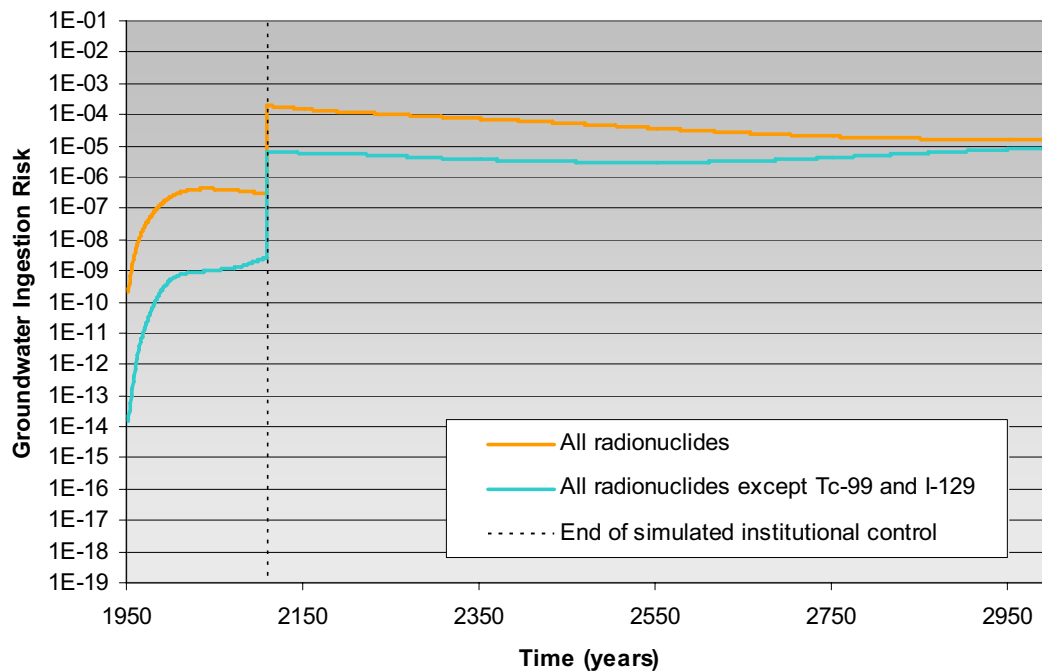
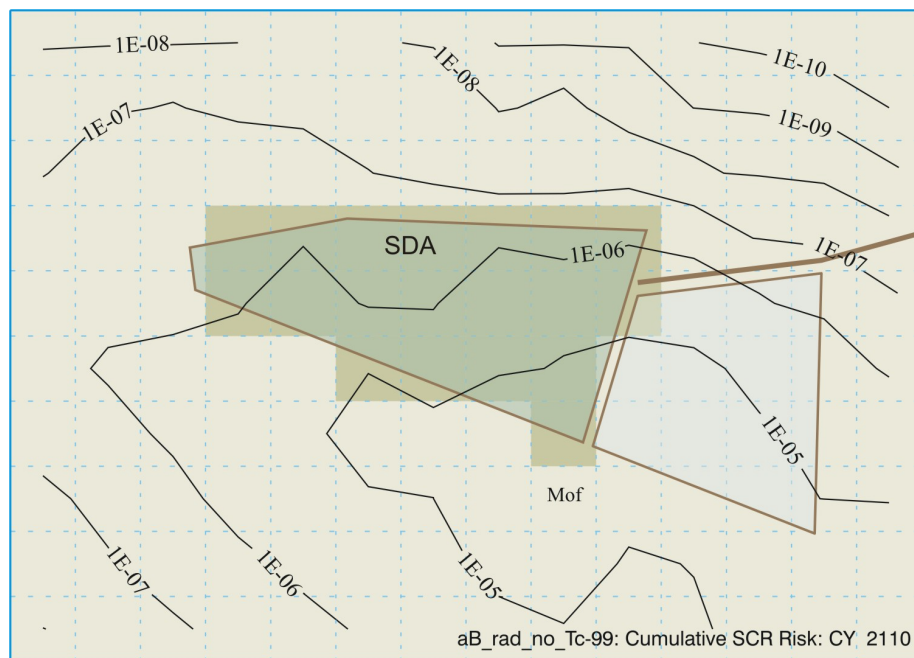


Figure E-21. Groundwater ingestion risk for radionuclides, including and excluding technetium-99 and iodine-129.



G1569-04

Mof = Maximum value outside fence = 5E-05

Figure E-22. Peak cumulative groundwater ingestion risk isopleths for radionuclides, excluding technetium-99, for comparison to Figure E-18.

Table E-3. Original waste generators and general locations of primary contaminants of concern in the Subsurface Disposal Area.

Contaminant	Waste Generator ^a	Portion (%)	Initial Inventory ^b	Areas of Highest Densities
Am-241	Rocky Flats Plant	100.0	2.43E+05	Pits
C-14	INL Site	100.0	7.31E+02	Trenches and soil vaults
Cs-137	INL Site	100.0	1.68E+05	Trenches and soil vaults
I-129	INL Site	100.0	1.88E-01	Trenches and soil vaults
Pb-210	Rocky Flats Plant	NA ^c	NA ^c	Pits
Pb-210	INL Site	100.0 ^c	5.62E-07 ^c	Trenches
Pu-238 ^d	Rocky Flats Plant	88.7	1.85E+03	Pits
Pu-238 ^d	INL Site	11.3	2.35E+02	Trenches
Pu-239	Rocky Flats Plant	98.3	6.30E+04	Pits
Pu-239	INL Site	1.7	1.08E+03	Trenches
Pu-240	Rocky Flats Plant	96.6	1.40E+04	Pits
Pu-240	INL Site	3.4	5.03E+02	Trenches
Ra-226	Rocky Flats Plant	NA ^e	NA ^e	Pits
Ra-226	INL Site	100.0 ^e	6.53E+01 ^e	Trenches
Ra-228	Rocky Flats Plant	NA ^f	NA ^f	Pits
Ra-228	INL Site	100.0 ^f	3.66E-05 ^f	Trenches
Sr-90	INL Site	100.0	1.36E+05	Trenches and soil vaults
Tc-99	INL Site	100.0	4.23E+01	Trenches and soil vaults
Th-228	Rocky Flats Plant	NA ^g	NA ^g	Pits
Th-228	INL Site	100.0 ^g	1.05E+01 ^g	Low-Level Waste Pit
Carbon tetrachloride	Rocky Flats Plant	100.0	7.90E+08	Pits
1,4-Dioxane	Rocky Flats Plant	96.0	1.87E+06	Pits (with carbon tetrachloride)
1,4-Dioxane	INL Site	4.0	4.24E+04	Pits, trenches, and soil vaults
Methylene chloride	Rocky Flats Plant	100.0	1.41E+07	Pits
Nitrate (as nitrogen)	Rocky Flats Plant	89.1	4.06E+08	Pits and Pad A
Nitrate (as nitrogen)	INL Site	10.9	4.98E+07	Pits
Tetrachloroethylene	Rocky Flats Plant	100.0	9.87E+07	Pits (with carbon tetrachloride)
Trichloroethylene	Rocky Flats Plant	99.6	8.92E+07	Pits (with carbon tetrachloride)
Trichloroethylene	INL Site	0.4	4.07E+05	Trenches

a. Portions listed for INL Site waste may include small amounts from off-INL Site waste generators, excluding Rocky Flats Plant.

b. Initial inventory at time of disposal; units are curies for radionuclides and grams for nonradionuclides.

c. Risk is attributable to ingrowth of Pb-210 from Pu-238 and U-238; initial disposal quantities are not significant.

d. Pu-238 is not, itself, a COC. However, Pu-238 decays to two COCs (i.e., Pb-210 and Ra-226).

e. Risk is attributable to ingrowth of Ra-226 from Pu-238 and U-238; initial disposal quantities are not significant.

f. Risk is attributable to ingrowth of Ra-228; initial disposal quantities are not significant. Ingrowth is primarily associated with Pu-240 from Rocky Flats Plant.

g. Risk is attributable to ingrowth of Th-228; initial disposal quantities are not significant. Ingrowth is primarily associated with Pu-240 from Rocky Flats Plant, though a small portion arises and then decays from U-232.

INL = Idaho National Laboratory

To address uncertainties associated with model results, simulations were extended to 10,000 years for long-lived radionuclides that did not reach peak simulated concentrations in 1,000-year simulations. Residential scenario risk estimates are greater than 1E-05 in the 10,000-year simulation period for eight radionuclides: Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. These eight radionuclides are identified as secondary COCs for the Operable Unit 7-13/14 feasibility study. Table E-4 lists secondary COCs. Figure E-23 shows groundwater ingestion risk for all eight radionuclides. Figures E-24 and E-25 show peak groundwater risk isopleths at the end of the 10,000-year simulation period for regional and local scales.

Table E-4. Secondary radionuclide contaminants of concern based on 10,000-year future residential scenario groundwater ingestion peak risk estimates and groundwater concentrations.

Radionuclide	Peak Risk	Calendar Year	Peak Aquifer Concentration	Maximum Contaminant Level
Ac-227	2E-05	12000	2.31E+00 pCi/L	15 pCi/L ^a
Np-237	1E-04	12000	8.68E+01 pCi/L	15 pCi/L ^a
Pa-231	1E-05	12000	3.20E+00 pCi/L	15 pCi/L ^a
U-233	2E-05	5352	1.30E+01 pCi/L	2.9E+05 pCi/L ^b
U-234	4E-05	12000	2.71E+01 pCi/L	1.87E+05 pCi/L ^b
U-235	1E-05	12000	7.18E+00 pCi/L	6.49E+01 pCi/L ^b
U-236	1E-05	12000	8.29E+00 pCi/L	1.94E+03 pCi/L ^b
U-238	9E-05	12000	4.71E+01 pCi/L	1.01E+01 pCi/L ^b
Total uranium ^c	NA	12000	1.44E-01 mg/L ^c	3.00E-02 mg/L ^c

a. The limit is 15 pCi/L for total alpha (40 CFR 141).

b. The limit is 3E-02 mg/L (30 µg/L) for total uranium. To compare concentrations of uranium isotopes, 3E-02 mg/L is converted to the equivalent activity for each isotope.

c. Total uranium is presented only for assessing simulated concentrations against the maximum contaminant limit. The peak concentration for total uranium is given in mg/L, developed by converting activity for each uranium isotope to mass and summing the results regardless of the timing of the peak. The maximum contaminant level is exceeded for total uranium, which is attributable almost completely to U-238.

Secondary contaminant of concern based on 10,000-year risk or concentration

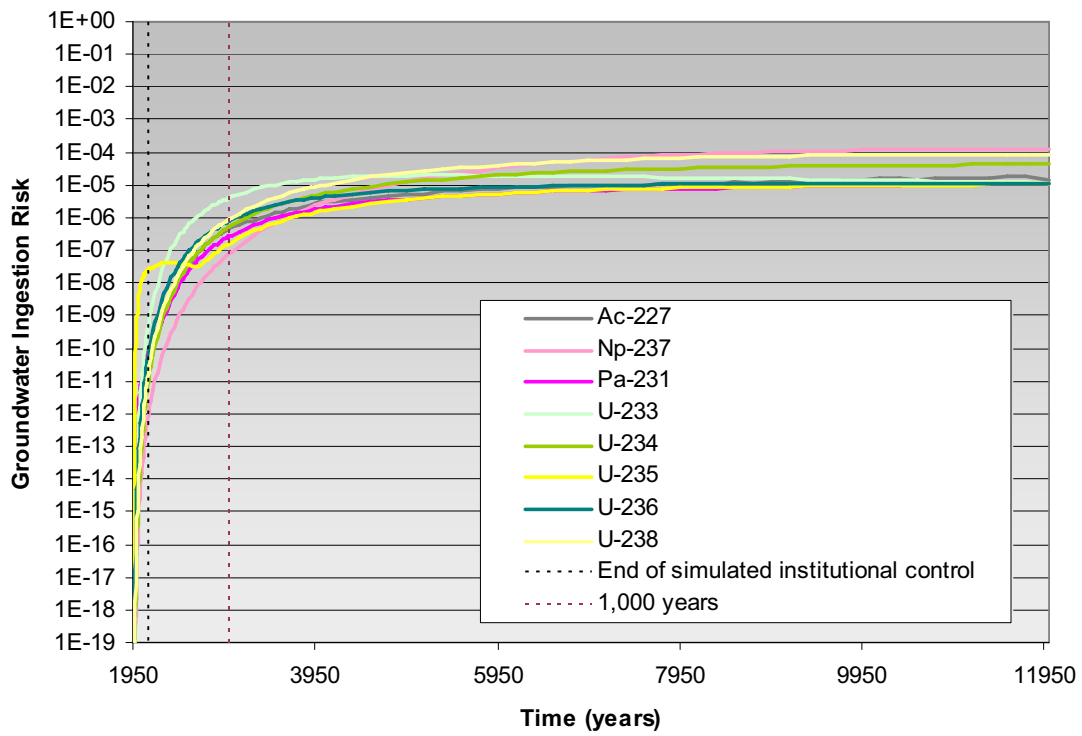
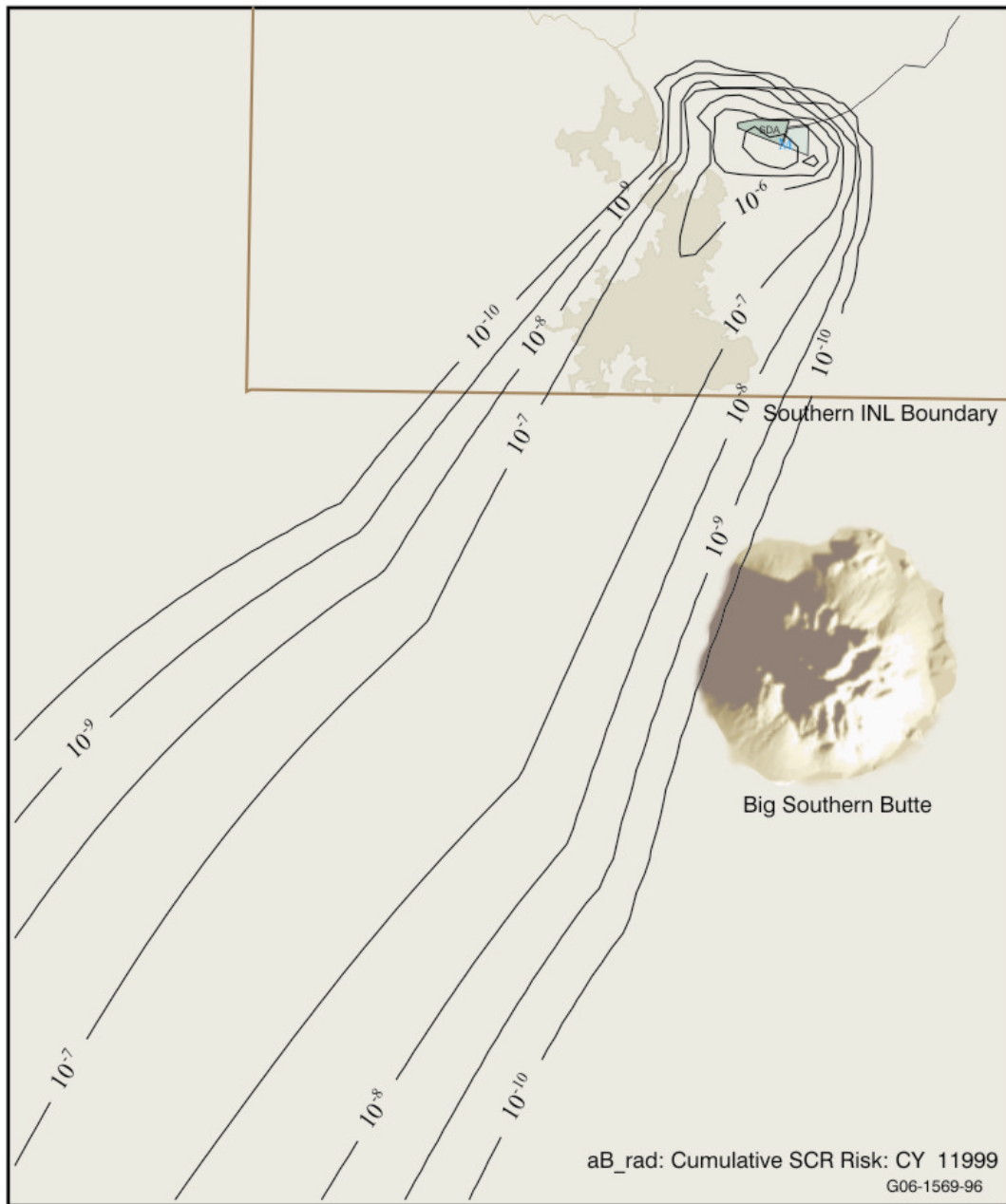
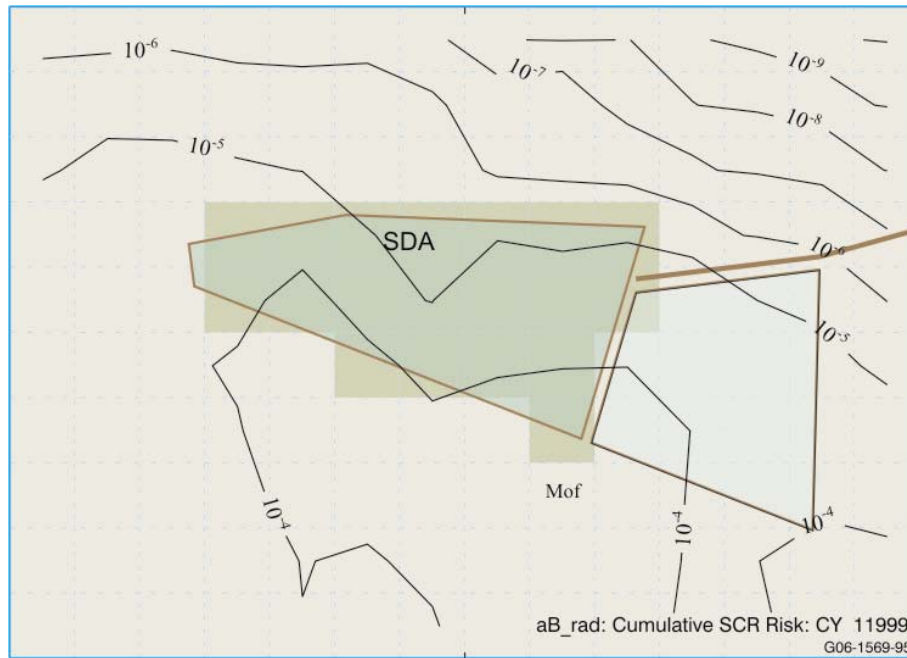


Figure E-23. Simulated 10,000-year groundwater ingestion risk for contaminants that peak after 1,000 years.



M=Max value=2.8E-004

Figure E-24. Peak groundwater risk isopleths for radionuclides at the end of the 10,000-year groundwater simulation period for the regional refined grid.



Mof=Max value outside fence=3.15E-004

Figure E-25. Peak cumulative groundwater risk isopleths for radionuclides at the end of the 10,000-year groundwater simulation period for the local refined grid.

E-1.2.3 Bases for the Feasibility Study

According to an assumption in the Second Addendum (Holdren and Broomfield 2004) remedial action will be implemented for Operable Unit 7-13/14 if risk estimates exceed threshold values or simulated aquifer concentrations exceed MCLs. As demonstrated by the modeling and baseline risk assessment presented in this RI/BRA, these conditions are identified; therefore, a feasibility study will be prepared to evaluate remedial alternatives. The Operable Unit 7-13/14 feasibility study should focus on remedial alternatives that address the primary COCs identified in Tables E-1 and E-2.

Source-term information developed through records research, geophysical surveys, inventory reconstruction, and mapping have proven reliable through probing and retrieval demonstrations. This information, in conjunction with risk estimates, provides a good foundation for the feasibility study. As described in Table E-3, high densities of fission- and activation-product COCs generated through reactor operations at the INL Site (i.e., C-14, Tc-99, I-129, and Sr-90) are located primarily in trenches and soil vaults. Conversely, Rocky Flats Plant-generated COCs—VOCs, nitrate, and actinides including Am-241, plutonium isotopes, and their long-lived progeny (i.e., Ra-226, Ra-228, and Pb-210)—are located mostly in pits. Roughly half of the total nitrate in the SDA is located on Pad A. Both INL Site- and Rocky Flats Plant-generated COCs contribute to surface exposure pathway risk. Groundwater pathway primary COCs include VOCs and nitrate, which originated at the Rocky Flats Plant, and Tc-99 and I-129, which originated at the INL Site. Secondary groundwater pathway COCs are long-lived decay-chain actinides associated with Rocky Flats Plant waste: Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. Most of the waste producing these decay-chain progeny is located in pits, though a sizable fraction of uranium-related waste is on Pad A.

Preliminary remediation goals should be defined for primary COCs. Goals for surface exposure pathways should be predicated on reducing exposure-point concentrations (e.g., concentrations in soil and air) to protective levels. Remediation goals for the groundwater pathway should be based, at least in part, on anticipated performance of the surface barrier. The surface barrier is an element of final remediation for Operable Unit 7-13/14 because DOE, DEQ, and EPA recognize the impracticality of returning the SDA to a pristine state. A surface barrier is required to address contamination remaining at the site in two ways: (1) limiting infiltration and consequent transport downward through the vadose zone and aquifer and (2) inhibiting transport upward to the surface by plants and burrowing animals.

Simulations showing gross overpredictions (up to three orders of magnitude) of vadose zone and aquifer concentrations for Tc-99 and I-129 (see Section 5.2.5) should be refined before preliminary remediation goals are established for the feasibility study. These contaminants are modeled as highly mobile (i.e., with a distribution coefficient of 0 mL/g), which is based on current literature; however, monitoring data clearly refute rapid release from the source. Rather than assuming that these contaminants are available for immediate release through surface washoff, slower release through distributed container failure should be evaluated. Initial research indicates that many waste forms containing Tc-99 and I-129 were buried in welded stainless steel containers. If sufficient information can be collected to support a new model run for the feasibility study, a revised feasibility study baseline should be developed for Tc-99 and I-129.

Modeling and risk assessment for trichloroethylene should be refined early in development of the feasibility study to confirm that trichloroethylene is a COC and to provide a better basis for defining preliminary remediation goals. Trichloroethylene was semiquantitatively evaluated in the RI/BRA by scaling its inventory against carbon tetrachloride to estimate risk. Trichloroethylene is an organic solvent contained primarily in Rocky Flats Plant Series 743 sludge and is largely collocated with carbon tetrachloride.

Secondary COCs are defined based on the 10,000-year simulation period. Secondary COCs should not be direct targets for focused analysis of alternatives in the feasibility study (e.g., no preliminary remediation goals or additional grout case for actinides), but the long-term effectiveness of all assembled alternatives for these COCs should be evaluated and presented in the feasibility study. The feasibility study should include a sensitivity case to show that grouting would not effectively address secondary COCs in the far future. In addition, the feasibility study should evaluate the effectiveness of a surface barrier (assumed to be effective indefinitely) and retrieval (which is scalable to any size for targeted waste forms) in reducing long-term risk for these secondary COCs. Secondary COCs also should be identified as analytes for environmental monitoring to expedite periodic review of their status and to ensure that remedies are protective.

E-1.2.4 Remedial Action Objectives

As indicated in the Second Addendum (Holdren and Broomfield 2004), the feasibility study will be based on the assumption that source-term control will sufficiently reduce risk. Methods to mitigate contaminants that have already been released will not be evaluated in the Operable Unit 7-13/14 feasibility study, except to address continued operation of the vapor vacuum extraction system. Based on this assumption, remedial action objectives for Operable Unit 7-13/14 are provided in the Second Addendum and remain appropriate for developing the feasibility study. The only modifications are to replace the ABRA with this RI/BRA as the basis and to reduce the cumulative hazard index from 2 to 1. The first two remedial action objectives are related to risk thresholds. The last three objectives express the fundamental assumption that remedial action at the SDA will include an engineered surface barrier. Remedial action objectives are:

- Limit cumulative human health cancer risk for all exposure pathways to less than or equal to $1E-04$
- Limit noncancer risk for all exposure pathways to a cumulative hazard index of less than 1 for current and future workers and future residents
- Inhibit migration of COCs, as identified in the RI/BRA, into the vadose zone and the underlying aquifer
- Inhibit exposures of ecological receptors to COCs in soil and waste with concentrations greater than or equal to 10 times background values and with a hazard quotient greater than or equal to 10
- Inhibit transport of COCs to the surface by plants and animals.

E-1.3 References

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CONTENTS

ABSTRACT.....	iii
EXECUTIVE SUMMARY	v
ACKNOWLEDGMENTS	xlix
ACRONYMS.....	xcvii
1. INTRODUCTION.....	1-3
1.1 Purpose	1-3
1.2 Scope	1-3
1.3 Schedule	1-4
1.4 Regulatory Background.....	1-4
1.5 Report Organization	1-8
1.6 References	1-8
2. SITE BACKGROUND	2-5
2.1 Location and Description	2-6
2.2 Physical Characteristics.....	2-6
2.2.1 Physiography.....	2-6
2.2.2 Meteorology and Climatology	2-8
2.2.3 Regional Surface and Subsurface Geology	2-12
2.2.4 Radioactive Waste Management Complex Surface and Subsurface Geology.....	2-13
2.2.5 Seismic Activity.....	2-14
2.2.6 Volcanology	2-20
2.2.7 Surface Soil	2-22
2.2.8 Surface Hydrology	2-23
2.2.9 Subsurface Hydrology.....	2-26
2.3 Geologic and Hydrologic Investigations at the Radioactive Waste Management Complex	2-40
2.3.1 Advanced Tensiometer Investigation.....	2-40
2.3.2 Lysimeter Investigations	2-45
2.3.3 U.S. Geological Survey 1999 Spreading Area Tracer Test.....	2-51
2.3.4 Effects of Upgradient Aquifer Plumes	2-53
2.4 Flora and Fauna	2-60

2.5	Demography	2-61
2.5.1	Populations on the Idaho National Laboratory Site	2-61
2.5.2	Populations off the Idaho National Laboratory Site.....	2-63
2.5.3	Shoshone-Bannock Tribal Interests	2-63
2.6	Land Use.....	2-64
2.6.1	Current Land Use	2-64
2.6.2	Radioactive Waste Management Complex Current and Future Land Use	2-66
2.7	Cultural Resources.....	2-67
2.7.1	Regional Cultural Resources Overview	2-67
2.7.2	Local Cultural Resources	2-68
2.8	References	2-70
3.	WASTE AREA GROUP 7 DESCRIPTION AND BACKGROUND	3-9
3.1	Operational Background.....	3-10
3.1.1	Analysis of Collocated Facilities for Waste Area Group 7	3-10
3.1.2	Historical Operations from 1952 to 1985.....	3-11
3.1.3	Radioactive Waste Management Complex Operations from 1985 to Present	3-21
3.1.4	Summary of Waste Shipped from Rocky Flats Plant.....	3-25
3.1.5	Subsurface Disposal Area Buried Waste Retrievals	3-40
3.1.6	Beryllium Reflector Block Grouting.....	3-61
3.1.7	Summary of Disposals in the Subsurface Disposal Area	3-64
3.1.8	Soil-Cover Maintenance and Subsidence Repair	3-64
3.2	Summary of Waste Area Group 7 Operable Units	3-79
3.2.1	Operable Unit 7-01, Subsurface Disposal Area Soil Vaults, Track 2 Investigation.....	3-79
3.2.2	Operable Unit 7-02, Acid Pit, Track 2 Investigation	3-82
3.2.3	Operable Unit 7-03, Nontransuranic-Contaminated Waste Pits and Trenches, Track 1 Investigation.....	3-84
3.2.4	Operable Unit 7-04, Air Pathway, Track 2 Investigation.....	3-84
3.2.5	Operable Unit 7-05, Surface Water Pathways and Surficial Sediments, Track 2 Investigation.....	3-86
3.2.6	Operable Unit 7-06, Groundwater Pathway, Track 2 Investigation.....	3-86
3.2.7	Operable Unit 7-07, Vadose Zone Radionuclides and Metals, Track 2 Investigation.....	3-87
3.2.8	Operable Unit 7-08, Organic Contamination in the Vadose Zone Remedial Investigation and Feasibility Study.....	3-89
3.2.9	Operable Unit 7-09, Transuranic Storage Area Releases, Track 1 Investigation.....	3-91
3.2.10	Operable Unit 7-10, Pit 9 Process Demonstration Interim Action.....	3-92

3.2.11	Operable Unit 7-11, Septic Tanks and Drain Fields, Track 1 Investigation	3-98
3.2.12	Operable Unit 7-12, Pad A, Remedial Investigation and Feasibility Study	3-98
3.2.13	Operable Unit 7-13, Transuranic Pits and Trenches Remedial Investigation and Feasibility Study	3-99
3.2.14	Operable Unit 7-13/14, Comprehensive Remedial Investigation and Feasibility Study.....	3-100
3.2.15	Active Low-Level Waste Disposal Operations	3-100
3.3	Source-Term Assessment	3-105
3.3.1	Historical Data Task.....	3-105
3.3.2	Recent and Projected Data Task.....	3-105
3.3.3	Contaminant Inventory Database for Risk Assessment	3-105
3.3.4	WasteOScope	3-106
3.3.5	Waste Information and Location Database	3-106
3.3.6	Inventory Updates	3-107
3.4	Contaminant Screening for the Baseline Risk Assessment	3-107
3.4.1	Human Health Contaminant Screening.....	3-107
3.4.2	Ecological Contaminant Screening	3-118
3.5	Geophysical Investigations.....	3-123
3.5.1	Confirmation of Subsurface Disposal Area Disposal Locations	3-123
3.5.2	Identification of Areas for In Situ Characterization	3-124
3.5.3	Identification of Areas for In Situ Treatment.....	3-127
3.5.4	Determination of Overburden and Waste Zone Thickness	3-129
3.5.5	Other Uses of Geophysical Analyses	3-129
3.6	Probing in the Subsurface Disposal Area	3-129
3.6.1	Probing Background.....	3-129
3.6.2	Type A Probes and Logging Instruments.....	3-131
3.6.3	Type B Probes and Instrumentation	3-134
3.6.4	Pit 9 Study Area	3-137
3.6.5	Depleted Uranium Focus Area.....	3-139
3.6.6	Organic Sludge Focus Area.....	3-140
3.6.7	Americium and Neptunium Focus Area.....	3-148
3.6.8	Uranium and Enriched Uranium Focus Area in Pit 5	3-152
3.6.9	Activated Metal Investigations.....	3-155
3.6.10	Waste Zone Moisture Monitoring Array.....	3-159
3.6.11	Type A Logging Results Used to Estimate Cover and Waste Zone Thickness.....	3-160
3.6.12	Continued Data Collection by Probes in the Subsurface Disposal Area.....	3-166
3.6.13	Data Integration.....	3-169
3.7	Actinide Retardation Studies	3-175

3.8	Analysis and Leaching of Pit 9 Waste Samples	3-182
3.8.1	Sample Collection Methods	3-182
3.8.2	Actinide Contamination	3-183
3.8.3	Aqueous Partitioning of Actinide Contaminants.....	3-186
3.8.4	Operational Speciation	3-187
3.9	Carbon-14 and Tritium from Activated Beryllium.....	3-188
3.9.1	Estimated Activity in Beryllium Blocks Buried in the Subsurface Disposal Area	3-189
3.9.2	Monitoring Beryllium Reflector Blocks	3-190
3.9.3	Activated Metal Monitoring.....	3-198
3.9.4	Transport Studies	3-198
3.10	Criticality Safety Study of the Subsurface Disposal Area.....	3-199
3.11	References	3-201
4.	NATURE AND EXTENT OF CONTAMINATION.....	4-17
4.1	Contaminants and Data Sources	4-18
4.1.1	Contaminants.....	4-19
4.1.2	Waste Zone Data	4-23
4.1.3	Surface Sample Data	4-78
4.1.4	Vadose Zone Data	4-83
4.1.5	Aquifer Data.....	4-91
4.1.6	Data Interpretation Considerations.....	4-93
4.2	Actinium-227.....	4-99
4.3	Americium-241	4-99
4.3.1	Waste Zone.....	4-99
4.3.2	Surface.....	4-100
4.3.3	Vadose Zone.....	4-100
4.3.4	Aquifer	4-108
4.3.5	Summary of Americium-241	4-114
4.4	Carbon-14.....	4-116
4.4.1	Waste Zone.....	4-116
4.4.2	Vadose Zone.....	4-117
4.4.3	Soil-Gas Monitoring near Soil Vault Rows 12 and 20 and Vapor Monitoring in the Subsurface Disposal Area Vadose Zone	4-123
4.4.4	Aquifer	4-127
4.4.5	Summary of Carbon-14.....	4-129

4.5	Cesium-137	4-131
4.5.1	Waste Zone.....	4-131
4.5.2	Surface.....	4-131
4.5.3	Vadose Zone.....	4-131
4.5.4	Aquifer	4-136
4.5.5	Summary of Cesium-137	4-136
4.6	Chlorine-36.....	4-137
4.6.1	Waste Zone.....	4-137
4.6.2	Vadose Zone.....	4-137
4.6.3	Aquifer	4-140
4.6.4	Summary of Chlorine-36.....	4-141
4.7	Tritium.....	4-143
4.8	Iodine-129	4-146
4.8.1	Waste Zone.....	4-146
4.8.2	Vadose Zone.....	4-146
4.8.3	Aquifer	4-147
4.8.4	Summary of Iodine-129	4-150
4.9	Niobium-94	4-152
4.9.1	Waste Zone.....	4-152
4.9.2	Vadose Zone.....	4-152
4.9.3	Aquifer	4-153
4.9.4	Summary of Niobium-94	4-153
4.10	Neptunium-237.....	4-154
4.10.1	Waste Zone.....	4-154
4.10.2	Vadose Zone.....	4-154
4.10.3	Aquifer	4-155
4.10.4	Summary of Neptunium-237.....	4-155
4.11	Protactinium-231	4-157
4.12	Lead-210.....	4-157
4.13	Plutonium-238, Plutonium-239, and Plutonium-240	4-158
4.13.1	Waste Zone.....	4-158
4.13.2	Surface.....	4-159
4.13.3	Vadose Zone.....	4-160
4.13.4	Aquifer	4-171
4.13.5	Plutonium Special Studies.....	4-185
4.13.6	Summary of Plutonium	4-187

4.14	Radium-226 and Radium-228	4-193
4.14.1	Waste Zone.....	4-193
4.14.2	Vadose Zone.....	4-193
4.14.3	Aquifer	4-196
4.14.4	Summary of Radium-226	4-197
4.15	Strontium-90.....	4-199
4.15.1	Waste Zone.....	4-199
4.15.2	Surface.....	4-199
4.15.3	Vadose Zone.....	4-199
4.15.4	Aquifer	4-201
4.15.5	Summary of Strontium-90.....	4-208
4.16	Technetium-99.....	4-210
4.16.1	Waste Zone.....	4-210
4.16.2	Vadose Zone.....	4-210
4.16.3	Aquifer	4-219
4.16.4	Summary of Technetium-99.....	4-222
4.17	Thorium-228.....	4-224
4.18	Uranium-233, Uranium-234, Uranium-235, Uranium-236, and Uranium-238	4-225
4.18.1	Methodology for Interpreting Uranium Monitoring Data.....	4-226
4.18.2	Waste Zone.....	4-231
4.18.3	Surface.....	4-232
4.18.4	Vadose Zone.....	4-233
4.18.5	Aquifer	4-257
4.18.6	Summary of Uranium.....	4-264
4.19	Nitrate (Inorganic Contaminant)	4-266
4.19.1	Waste Zone.....	4-266
4.19.2	Vadose Zone.....	4-266
4.19.3	Aquifer	4-270
4.19.4	Summary of Nitrate.....	4-271
4.20	Chromium.....	4-273
4.20.1	Waste Zone.....	4-273
4.20.2	Vadose Zone.....	4-273
4.20.3	Aquifer	4-275
4.20.4	Summary of Chromium.....	4-277

4.21	Other Inorganic Contaminants	4-280
4.21.1	Vadose Zone.....	4-280
4.21.2	Magnesium Chloride Brine	4-282
4.21.3	Aquifer	4-282
4.21.4	Summary of Other Inorganic Chemicals.....	4-285
4.22	Carbon Tetrachloride (Volatile Organic Compound).....	4-287
4.22.1	Waste Zone.....	4-288
4.22.2	Surface.....	4-289
4.22.3	Vadose Zone.....	4-291
4.22.4	Aquifer	4-302
4.22.5	Summary of Carbon Tetrachloride.....	4-306
4.23	1,4-Dioxane (Volatile Organic Compound).....	4-308
4.23.1	Waste Zone.....	4-308
4.23.2	Surface.....	4-309
4.23.3	Vadose Zone.....	4-309
4.23.4	Aquifer	4-309
4.23.5	Summary for 1,4-Dioxane.....	4-309
4.24	Methylene Chloride (Volatile Organic Compound).....	4-310
4.24.1	Waste Zone.....	4-310
4.24.2	Surface.....	4-310
4.24.3	Vadose Zone.....	4-310
4.24.4	Aquifer	4-311
4.24.5	Summary of Methylene Chloride.....	4-312
4.25	Tetrachloroethylene (Volatile Organic Compound).....	4-313
4.25.1	Waste Zone.....	4-313
4.25.2	Surface.....	4-314
4.25.3	Vadose Zone.....	4-314
4.25.4	Aquifer	4-316
4.25.5	Summary for Tetrachloroethylene	4-316
4.26	Trichloroethylene (Volatile Organic Compound)	4-318
4.26.1	Waste Zone.....	4-318
4.26.2	Surface.....	4-319
4.26.3	Vadose Zone.....	4-319
4.26.4	Aquifer	4-321
4.26.5	Summary for Trichloroethylene.....	4-321

4.27	Additional Ecological Contaminants of Potential Concern.....	4-323
4.27.1	Radionuclides of Potential Ecological Concern.....	4-324
4.27.2	Inorganic Ecological Contaminants of Potential Concern	4-327
4.27.3	Organic Ecological Contaminants of Potential Concern.....	4-327
4.28	Nature and Extent of Contamination Summary	4-329
4.28.1	Waste Zone.....	4-329
4.28.2	Surface.....	4-330
4.28.3	Vadose Zone Soil Moisture and Perched Water	4-330
4.28.4	Vadose Zone Cores	4-333
4.28.5	Vadose Zone Soil Gas	4-335
4.28.6	Aquifer	4-335
4.28.7	Ecological Contaminants of Potential Concern.....	4-338
4.28.8	Summary Figures	4-338
4.29	References	4-361
5.	CONTAMINANT FATE AND TRANSPORT.....	5-9
5.1	Source-Release Modeling.....	5-13
5.1.1	Source-Term Inventory	5-14
5.1.2	Container Failure Rates.....	5-31
5.1.3	Release Mechanisms and Release Rates	5-32
5.1.4	Contaminant Grouping for Modeling.....	5-35
5.1.5	Simulated Source Areas	5-37
5.1.6	Infiltration Rates.....	5-46
5.1.7	Source-Term Model Calibration	5-50
5.2	Dissolved-Phase Transport Modeling	5-50
5.2.1	Dissolved-Phase Flow and Transport Conceptual Model	5-50
5.2.2	Predecessor Models.....	5-52
5.2.3	Overview of Improvements to the Ancillary Basis for Risk Analysis Model	5-54
5.2.4	Baseline Model Development and Description.....	5-56
5.2.5	Base-Case Simulations for the Baseline Risk Assessment	5-94
5.2.6	Baseline Risk Assessment Sensitivity Simulations.....	5-136
5.3	Volatile Organic Compound Modeling.....	5-153
5.3.1	Volatile Organic Compound Transport Model Development.....	5-153
5.3.2	Volatile Organic Compound Transport Model Calibration	5-158
5.4	Gaseous-Phase Radionuclide Modeling	5-166
5.4.1	Carbon-14 Partitioning from Column Experiments	5-166
5.4.2	Carbon-14 Beryllium Near-Field Simulation.....	5-167
5.4.3	Carbon-14 Dual-Continua Vadose Zone Simulation	5-167

5.5	Biotic Transport.....	5-171
5.5.1	Biotic Model Methodology	5-171
5.5.2	Methodology for Determining DOSTOMAN-Rate Constants.....	5-175
5.5.3	Flora—Current Scenario	5-176
5.5.4	Flora—100-Plus-Year Scenario	5-176
5.5.5	Fauna—Current Scenario	5-180
5.5.6	Fauna—100-Plus-Year Scenario.....	5-183
5.5.7	Biotic-Model Calibration	5-185
5.5.8	Summary	5-185
5.6	Summary and Conclusions.....	5-185
5.7	References	5-191
6.	BASELINE RISK ASSESSMENT	6-13
6.1	Assumptions for Baseline Risk Assessment.....	6-13
6.2	Human Health Exposure Assessment.....	6-14
6.2.1	Exposure Scenarios and Conceptual Site Model.....	6-15
6.2.2	Media Concentrations	6-17
6.2.3	Quantification of Exposure	6-20
6.3	Toxicity Profiles for Human Health Contaminants of Potential Concern	6-26
6.3.1	Chemicals.....	6-26
6.3.2	Radionuclides.....	6-32
6.4	Risk Characterization	6-37
6.4.1	Generalized Approach.....	6-38
6.4.2	Estimates of the Potential Human Health Risk within 1,000 Years.....	6-39
6.4.3	10,000-Year Groundwater Ingestion Risks	6-62
6.4.4	Risk and Concentration Plots	6-65
6.5	Uncertainties in the Human Health Baseline Risk Assessment.....	6-106
6.5.1	Scenario Uncertainty	6-106
6.5.2	Model Uncertainty	6-106
6.5.3	Parameter Uncertainty.....	6-108
6.6	Inadvertent Intruder Analysis	6-134
6.6.1	Locations for the Intruder Scenario.....	6-134
6.6.2	Intruder Scenario Assessment	6-140
6.6.3	Intruder Scenario Results	6-146

6.7	Ecological Risk Assessment.....	6-148
6.7.1	General Approach	6-148
6.7.2	Waste Area Group 7 Ecological Characterization	6-150
6.7.3	Contaminants of Ecological Concern.....	6-158
6.7.4	Exposure Analysis.....	6-163
6.7.5	Ecological Risk Estimates.....	6-171
6.7.6	Ecological Risk Evaluation	6-178
6.8	Baseline Risk Assessment Summary.....	6-180
6.9	References	6-187
7.	SUMMARY AND CONCLUSIONS OF THE OPERABLE UNIT 7-13/14 REMEDIAL INVESTIGATION AND BASELINE RISK ASSESSMENT	7-5
7.1	Overview	7-5
7.1.1	Summary of Section 1—Introduction	7-6
7.1.2	Summary of Section 2—Site Background	7-6
7.1.3	Summary of Section 3—Waste Area Group 7 Description and Background	7-10
7.1.4	Summary of Section 4—Nature and Extent of Contamination.....	7-11
7.1.5	Summary of Section 5—Contaminant Fate and Transport	7-18
7.1.6	Summary of Section 6—Baseline Risk Assessment	7-23
7.2	Conclusions of the Remedial Investigation and Baseline Risk Assessment	7-30
7.2.1	Basis for Conclusions—Overall Uncertainty in Modeling and Risk Assessment.....	7-31
7.2.2	Contaminants of Concern.....	7-32
7.2.3	Bases for the Feasibility Study.....	7-43
7.2.4	Remedial Action Objectives.....	7-45
7.3	References	7-45
8.	REFERENCES	8-1

FIGURES

1-1.	Idaho National Laboratory	1-6
1-2.	Radioactive Waste Management Complex	1-7
2-1.	Idaho National Laboratory Site on the Snake River Plain Aquifer.....	2-7
2-2.	Radioactive Waste Management Complex relative to the Idaho National Laboratory Site, the diversion dam on Big Lost River, and the flood control spreading areas	2-9
2-3.	Topographic features of the Radioactive Waste Management Complex and surrounding terrain	2-10
2-4.	Wind rose from the Radioactive Waste Management Complex area from 1980 to 2004	2-12
2-5.	Cross section trending west to east through the Subsurface Disposal Area	2-15
2-6.	Cross section trending southwest to northeast through the Subsurface Disposal Area	2-16
2-7.	Volcanic rift zones	2-17
2-8.	Earthquake epicenters compiled from regional seismic networks for magnitudes greater than 2.5 occurring from 1872 to 2004	2-18
2-9.	Epicenters of earthquakes occurring from 1972 to 2004 compiled by the Idaho National Laboratory Seismic Monitoring Program	2-19
2-10.	Volcanic rift zones and Holocene basalt lava fields	2-21
2-11.	Surface water features of the Idaho National Laboratory Site.....	2-24
2-12.	Daily mean stream flow to the spreading areas at the Idaho National Laboratory Site diversion dam on the Big Lost River from September 1984 to 2005	2-25
2-13.	Historical floods in the Subsurface Disposal Area	2-27
2-14.	Perched water wells at the Radioactive Waste Management Complex	2-33
2-15.	Aquifer water-level contours in the vicinity of the Radioactive Waste Management Complex, based on data collected in June 2005	2-36
2-16.	Aquifer water-level contours upgradient of the Radioactive Waste Management Complex, based on data collected in June 2005	2-37
2-17.	Aquifer water-level contours downgradient of the Radioactive Waste Management Complex, based on data collected in June 2005	2-38
2-18.	Pump test results from RWMC area wells.....	2-39
2-19.	Advanced tensiometers at the Radioactive Waste Management Complex	2-42

FIGURES (continued)

2-20.	Suction lysimeters at the Radioactive Waste Management Complex.....	2-46
2-21.	Surface water features and select monitoring wells near the Radioactive Waste Management Complex	2-52
2-22.	Approximate boundaries of select aquifer plumes based on concentrations in 2003 for the Reactor Technology Complex, Idaho Nuclear Technology and Engineering Center, Central Facilities Area, and Radioactive Waste Management Complex areas	2-55
2-23.	Distribution of Cl-36:Cl ratios in the Snake River Plain Aquifer	2-56
2-24.	Distribution of $\delta^{15}\text{N}$ and $\delta^{18}\text{O}_{\text{nitrate}}$ values in the Snake River Plain Aquifer and plot of $\delta^{15}\text{N}$ versus $\delta^{18}\text{O}_{\text{nitrate}}$	2-57
2-25.	Distribution of $\delta^{34}\text{S}$ and $\delta^{18}\text{O}_{\text{sulfate}}$ values in the Snake River Plain Aquifer and plot of $\delta^{34}\text{S}$ versus $\delta^{18}\text{O}_{\text{sulfate}}$	2-58
2-26.	Regional human and ecological land use—current state	2-62
2-27.	Human and ecological land uses at the Idaho National Laboratory Site	2-65
3-1.	Facilities and structures within the Radioactive Waste Management Complex	3-13
3-2.	Waste contained in a waste insert being transferred from a shipping cask to a removable crib in Trench 55 in 1973.....	3-22
3-3.	Historical and ongoing waste retrievals in the Subsurface Disposal Area.....	3-41
3-4.	Retrieval in Pit 1 in 1969	3-42
3-5.	Orderly stacked drums exposed during the 1969 retrieval in Pit 1	3-43
3-6.	Workers within the containment structure during the Early Waste Retrieval Project (1976 through 1978)	3-47
3-7.	Pad A during emplacement of waste drums retrieved from Pits 11 and 12 during the Initial Drum Retrieval Project.....	3-49
3-8.	Drums exposed on Pad A during the Initial Penetration Project	3-50
3-9.	Series 745 evaporator salts retrieved during the Pad A Initial Penetration Project	3-51
3-10.	Flooding in Pit 9 during the spring 1969 snowmelt flooding event.....	3-52
3-11.	Operable Unit 7-10 Glovebox Excavator Method Project facility.....	3-53
3-12.	Operable Unit 7-10 Glovebox Excavator Method Project excavator interface with the Retrieval Confinement Structure	3-53

FIGURES (continued)

3-13.	Probe at Location P9-20 penetrating dumped waste drums within the Operable Unit 7-10 Glovebox Excavator Method Project retrieval area	3-55
3-14.	Accelerated Retrieval Project Retrieval Enclosure, attached equipment-service and waste-handling airlocks, and planned expansion	3-57
3-15.	Accelerated Retrieval Project excavator retrieving waste from Pit 4	3-58
3-16.	Orderly stacked waste drums at the western end of the Accelerated Retrieval Project retrieval area	3-59
3-17.	Approximate locations of beryllium disposal at the Subsurface Disposal Area	3-62
3-18.	Life spans of trenches, pits, Pad A, and soil vault rows at the Subsurface Disposal Area	3-65
3-19.	Transuranic and low-level waste disposal locations in the Subsurface Disposal Area.....	3-67
3-20.	Ponding and subsidence in the Subsurface Disposal Area, spring 2005.....	3-73
3-21.	Western ditch and culvert modification to improve drainage in 2004.....	3-74
3-22.	Subsurface Disposal Area dike penetration with a one-way flapper valve.....	3-74
3-23.	Subsidence in the Subsurface Disposal Area.....	3-78
3-24.	Subsidence in the Subsurface Disposal Area.....	3-78
3-25.	Active Low-Level Waste Disposal Facility in contiguous Pits 17 through 20	3-101
3-26.	Contact-handled low-level waste forecasts compared to actual volumes	3-103
3-27.	Remote-handled low-level waste forecasts compared to actual volumes	3-104
3-28.	Magnetic geophysical survey of the Subsurface Disposal Area	3-125
3-29.	Electromagnetic geophysical survey of the Subsurface Disposal Area	3-126
3-30.	Magnetic geophysical survey for Soil Vault Row 12	3-127
3-31.	Soil-gas survey results depicted as colored dots overlaid on the Trench 58 geophysical survey.....	3-128
3-32a.	Advanced tensiometer.....	3-132
3-32b.	Water-level transducer and data logger	3-132
3-32c.	Soil-moisture resistivity probe.....	3-132
3-32d.	Direct-push Type B tensiometer	3-132

FIGURES (continued)

3-33.	Typical probe suite deployed in the Subsurface Disposal Area.....	3-133
3-34.	Probes installed in the Pit 9 study area	3-138
3-35.	Probe clusters installed in and around the Depleted Uranium Focus Area in the western end of Pit 10.....	3-141
3-36.	Probes installed in the Organic Sludge Focus Area in the eastern end of Pit 4	3-145
3-37.	Relationship of shallow soil-gas survey and Type A probe placement in the eastern end of Pit 4.....	3-147
3-38.	Relationship of geophysical survey and Type A probe placement in the eastern end of Pit 4.....	3-147
3-39.	Probes installed in the Americium and Neptunium Focus Area in the central part of Pit 10 ...	3-150
3-40.	Probes installed in the Uranium and Enriched Uranium Focus Area in Pit 5	3-153
3-41.	Probes installed in the Activated Metal Focus Area	3-158
3-42.	Probes installed to develop the waste zone moisture monitoring array	3-161
3-43.	Temporary accumulations of surface water at the Subsurface Disposal Area during February 1995	3-165
3-44.	Chlorine slice and plume with moisture represented by probe bores in the Series 743 Focus Area	3-172
3-45.	Probing project focus areas at the Subsurface Disposal Area.....	3-173
3-46.	Frequency distribution of batch plutonium K_d values differentiated by the valence state of plutonium in the starting solution.....	3-177
3-47.	Neptunium adsorption on Sample IIS-INEEL-109 comparing the fit of Freundlich, Langmuir, and linear isotherms to the laboratory data	3-180
3-48.	Laboratory neptunium adsorption data for three soil samples showing similar slopes when fit with a Freundlich isotherm.....	3-181
3-49.	Plots of (A) Pu-239 versus Am-241 and (B) the Pu-239/Am-241 isotope ratio versus Am-241	3-185
3-50.	Average K_d values for leaching Pu-239 with low-ionic-strength leachate (deionized water) and high-ionic-strength leachate (100 mm sodium chloride) as a function of pH for interstitial soil samples and organic waste.....	3-187
3-51.	Advanced Test Reactor beryllium reflector block	3-189

FIGURES (continued)

3-52.	Beryllium disposal locations in the Subsurface Disposal Area	3-192
3-53.	Concentrations of airborne tritiated water vapor above beryllium blocks buried in Soil Vault Row 20	3-193
3-54.	Concentrations of tritiated water in soil moisture collected from a depth of 8.9 ft near activated beryllium in Soil Vault Row 20.....	3-194
3-55.	Concentrations of tritiated water in soil moisture collected from a depth of 14.8 ft near activated beryllium in Soil Vault Row 20.....	3-194
3-56.	Concentrations of tritiated water in soil moisture collected from a depth of 20.3 ft near activated beryllium in Soil Vault Row 20.....	3-195
3-57.	Correlation of concentrations of tritiated water in soil moisture collected from depths of 15 and 20 ft in Soil Vault Row 20	3-195
4-1.	Depth intervals analyzed in evaluation of nature and extent of contamination	4-18
4-2.	Density of americium-241 in the Subsurface Disposal Area.....	4-41
4-3.	Density of carbon-14 in the Subsurface Disposal Area	4-42
4-4.	Density of chlorine-36 in the Subsurface Disposal Area	4-43
4-5.	Density of cesium-137 in the Subsurface Disposal Area.....	4-44
4-6.	Density of all iodine-129 in the Subsurface Disposal Area	4-45
4-7.	Density of releasable iodine-129 in the Subsurface Disposal Area	4-46
4-8.	Density of niobium-94 in the Subsurface Disposal Area.....	4-47
4-9.	Density of neptunium-237 in the Subsurface Disposal Area.....	4-48
4-10.	Density of plutonium-238 in the Subsurface Disposal Area.....	4-49
4-11.	Density of plutonium-239 in the Subsurface Disposal Area.....	4-50
4-12.	Density of plutonium-240 in the Subsurface Disposal Area.....	4-51
4-13.	Composite of radium-226 density in the Subsurface Disposal Area	4-52
4-14.	Density of strontium-90 in the Subsurface Disposal Area.....	4-53
4-15.	Density of all technetium-99 in the Subsurface Disposal Area	4-54
4-16.	Density of releasable technetium-99 in the Subsurface Disposal Area	4-55
4-17.	Density of thorium-228 in the Subsurface Disposal Area	4-56

FIGURES (continued)

4-18.	Density of thorium-232 in the Subsurface Disposal Area	4-57
4-19.	Density of uranium-233 in the Subsurface Disposal Area.....	4-58
4-20.	Density of uranium-234 in the Subsurface Disposal Area.....	4-59
4-21.	Density of uranium-235 in the Subsurface Disposal Area.....	4-60
4-22.	Density of uranium-236 in the Subsurface Disposal Area.....	4-61
4-23.	Density of uranium-238 in the Subsurface Disposal Area.....	4-62
4-24.	Density of nitrate in the Subsurface Disposal Area	4-63
4-25.	Density of carbon tetrachloride in the Subsurface Disposal Area	4-64
4-26.	Density of 1,4-dioxane in the Subsurface Disposal Area	4-65
4-27.	Density of methylene chloride in the Subsurface Disposal Area.....	4-66
4-28.	Density of tetrachloroethylene in the Subsurface Disposal Area.....	4-67
4-29.	Density of trichloroethylene in the Subsurface Disposal Area	4-68
4-30.	Decay chain for the thorium decay series, including anthropogenic predecessors from weapons manufacturing and reactor operations.....	4-70
4-31.	Decay chain for the neptunium series	4-71
4-32.	Decay chain for the uranium series, including anthropogenic predecessors from weapons manufacturing and reactor operations.....	4-72
4-33.	Decay chain for the actinium series, including anthropogenic predecessors from weapons production and reactor operations.....	4-73
4-34.	Type A probes from which nuclear logging data were obtained	4-75
4-35.	Instrumented probes that have collected soil moisture from focus areas in the Subsurface Disposal Area.....	4-77
4-36.	Surface soil sampling locations around the Radioactive Waste Management Complex	4-79
4-37.	Surface soil sampling locations at the Subsurface Disposal Area	4-80
4-38.	Surface soil sampling locations at the Transuranic Storage Area.....	4-81
4-39.	Vegetation sampling areas at the Radioactive Waste Management Complex	4-82
4-40.	Surface water run-off sampling locations at the Radioactive Waste Management Complex.....	4-82

FIGURES (continued)

4-41.	Shallow-depth lysimeters located at depths from 0 to 35 ft.....	4-84
4-42.	Lysimeters located in the intermediate-depth vadose zone at depths from 35 to 140 ft.....	4-85
4-43.	Lysimeters located in the deep vadose zone at depths greater than 140 ft	4-86
4-44.	Locations of core sample extractions in the Radioactive Waste Management Complex	4-87
4-45.	Wells in the vicinity of the Subsurface Disposal Area with permanent vapor sampling ports.....	4-89
4-46.	Vapor sampling port depths and numbers.....	4-90
4-47.	Radioactive Waste Management Complex aquifer monitoring wells.....	4-92
4-48.	Waste zone monitoring near or in Soil Vault Rows 12 and 20.....	4-124
4-49.	Carbon-14 detections in vapor ports	4-126
4-50.	Carbon-14 gas sampling wells and detections	4-127
4-51.	Plutonium concentrations in soil moisture and perched water from 1972 to 2004.....	4-188
4-52.	Plutonium concentrations in aquifer samples from 1972 to 2004.....	4-189
4-53.	Technetium-99 concentration history for Lysimeters D06:DL01 and D06:DL02 showing possible migration from 44 to 88 ft starting in 2003	4-214
4-54.	Technetium-99 results in core samples collected in 1999 to 2000 and 2003.....	4-218
4-55.	Core samples and soil moisture samples with technetium-99 detections	4-219
4-56.	Reasonable agreement between alpha spectrometry and inductively coupled plasma mass spectrometry analysis of uranium-234.....	4-228
4-57.	Poor agreement between alpha spectrometry and inductively coupled plasma mass spectrometry analysis of U-235	4-228
4-58.	Reasonable agreement between alpha spectrometry and inductively coupled plasma mass spectrometry analysis of uranium-238.....	4-229
4-59.	Comparison of U-238:U-235 activity ratios measured by isotope dilution thermal ionization mass spectrometry and alpha spectrometry in 1999 and 2000.....	4-229
4-60.	Aquifer background activity ratios for U-238:U-235 in Well M11S.....	4-230
4-61.	Uranium concentrations at Lysimeter PA02:L16 showing decreasing concentrations in early Fiscal Year 2004	4-241

FIGURES (continued)

4-62.	Uranium concentrations at Lysimeter W08:L13 showing decreasing concentrations beginning late in Fiscal Year 2003	4-241
4-63.	Uranium concentrations at Lysimeter D06:DL01.....	4-249
4-64.	Decreasing uranium concentrations at Lysimeter D06:DL02.....	4-249
4-65.	Increasing uranium concentrations at Lysimeter TW1:DL04.....	4-250
4-66.	Uranium concentration trend at location IE6:DL34	4-257
4-67.	Concentration history of U-235/236 at aquifer Well M12S showing data from June 1998	4-264
4-68.	Correlation between U-234:U-238 and U-238:U-235 activity ratios showing uranium detected at Well M12S is characteristic of naturally occurring uranium.....	4-264
4-69.	Correlation between activity ratios for U-234:U-238 and U-238:U-235.....	4-265
4-70.	Nitrate trends in shallow lysimeters from 1997 through August 2004	4-267
4-71.	Lysimeter nitrate concentration over time at the western end of the Subsurface Disposal Area in the 35 to 140-ft depth interval.....	4-268
4-72.	Lysimeter nitrate concentration over time beneath Pad A at the 97-ft depth.....	4-268
4-73.	Lysimeter nitrate concentrations over time beneath Pad A at 44 and 88 ft	4-269
4-74.	Nitrate concentrations over time in samples from perched water Well USGS-92.....	4-270
4-75.	Concentration of nitrate (as nitrogen) in Radioactive Waste Management Complex aquifer monitoring Well M6S from 1992 to May 2004.....	4-271
4-76.	Radioactive Waste Management Complex aquifer monitoring wells with increasing chromium concentrations.....	4-275
4-77.	Chromium concentrations within a 1-mi radius are generally higher than concentrations within a 1 to 5-mi radius of the Radioactive Waste Management Complex.....	4-276
4-78.	Chromium concentrations in wells at the Radioactive Waste Management Complex	4-279
4-79.	Aquifer wells with concentrations of magnesium chloride brine	4-286
4-80.	Surface isolation flux chamber measurement locations and carbon tetrachloride emission rates.....	4-290
4-81.	Carbon tetrachloride concentrations (ppmv) in shallow soil gas measured during the 2000 shallow soil-gas survey	4-292
4-82.	Conceptual drawing of the carbon tetrachloride soil-gas plume before vapor vacuum extraction with treatment system operations.....	4-294

FIGURES (continued)

4-83.	Vertical profiles of carbon tetrachloride soil-gas concentrations for Wells 8801, 9301, and 9302 near the center of the Subsurface Disposal Area, averaged from April 1993 to October 1995	4-295
4-84.	Vertical profiles of carbon tetrachloride soil-gas concentrations for V- and VVE-series wells averaged from January 1995 to October 1995.....	4-296
4-85.	Carbon tetrachloride soil-gas concentration at the 78-ft depth timeline for Well 8801, Port 4	4-298
4-86.	Carbon tetrachloride soil-gas concentration at the 77-ft depth time history for Well 9301, Port 6	4-298
4-87.	Carbon tetrachloride soil-gas concentration time history for selected ports in Well 9V	4-299
4-88.	Carbon tetrachloride concentrations at the 70-ft depth just before commencement of vapor vacuum extraction with treatment system operations in January 1996 and in May 2005, after 9 years of operation	4-300
4-89.	Carbon tetrachloride concentrations in perched water in Well USGS-92	4-302
4-90.	Maximum carbon tetrachloride concentrations ($\mu\text{g/L}$) in the Snake River Plain Aquifer, in the vicinity of the Subsurface Disposal Area.....	4-304
4-91.	Carbon tetrachloride aquifer concentrations in monitoring wells in the vicinity of the Subsurface Disposal Area	4-305
4-92.	Recurring contaminants in vadose zone lysimeters (does not include volatile organic compounds).....	4-332
4-93.	Detected radionuclides in core samples between 1971 and 2003	4-334
4-94.	Constituents in aquifer monitoring wells.....	4-337
4-95.	Plan view and three-dimensional views of americium-241 detections in vadose zone core, lysimeters, and the aquifer	4-339
4-96.	Plan view and three-dimensional views of carbon-14 detections in vadose zone core, lysimeters, and the aquifer	4-340
4-97.	Plan view and three-dimensional view of chlorine-36 detections in vadose zone core, lysimeters, and the aquifer	4-341
4-98.	Plan view and three-dimensional view of cesium-137 detections in vadose zone core, lysimeters, and the aquifer	4-342
4-99.	Plan view and three-dimensional views of iodine-129 detections in vadose zone core, lysimeters, and the aquifer	4-343

FIGURES (continued)

4-100. Plan view and three-dimensional views of neptunium-237 in vadose zone core, lysimeters, and the aquifer	4-344
4-101. Plan view and three-dimensional views of plutonium-238 detections in vadose zone core, lysimeters, and the aquifer	4-345
4-102. Plan view and three-dimensional views of plutonium-239/240 detections in vadose zone core, lysimeters, and the aquifer	4-346
4-103. Plan view and three-dimensional views of radium-226 detections in vadose zone core, lysimeters, and the aquifer	4-347
4-104. Plan view and three-dimensional views of strontium-90 detections in vadose zone core, lysimeters, and the aquifer	4-348
4-105. Plan view and three-dimensional views of technetium-99 detections in vadose zone core, lysimeters, and the aquifer	4-349
4-106. Plan view and three-dimensional views of uranium-233 and -234 detections in vadose zone core, lysimeters, and the aquifer.....	4-350
4-107. Plan view and three-dimensional views of uranium-235/236 detections in vadose zone core, lysimeters, and the aquifer	4-351
4-108. Plan view and three-dimensional views of uranium-238 detections in vadose zone core, lysimeters, and the aquifer	4-352
4-109. Plan view and three-dimensional views of nitrate (as nitrogen) detections in vadose zone core, lysimeters, and the aquifer	4-353
4-110. Plan view and three-dimensional views of carbon tetrachloride in aqueous samples in the vadose zone and aquifer.....	4-354
4-111. Three-dimensional views of carbon tetrachloride in soil gas in the vadose zone	4-355
4-112. Plan view and three-dimensional views of methylene chloride in aqueous samples in the vadose zone and aquifer.....	4-356
4-113. Plan view and three-dimensional views of tetrachloroethylene detections in aqueous samples in the vadose zone and aquifer	4-357
4-114. Three-dimensional views of tetrachloroethylene in soil gas in the vadose zone	4-358
4-115. Plan view and three-dimensional views of trichloroethylene in aqueous samples in the vadose zone and aquifer.....	4-359
4-116. Three-dimensional views of trichloroethylene in soil gas in the vadose zone.....	4-360
5-1. Operable Unit 7-13/14 risk modeling modules.....	5-10

FIGURES (continued)

5-2.	Eighteen source areas simulated for all contaminants, except carbon-14, in the source-release model and specifically represented in the subsurface model domain	5-39
5-3.	Nine carbon-14 source areas simulated in the source-release model and specifically represented in the subsurface model domain	5-40
5-4.	Infiltration rates with averages by source area for dissolved-phase contaminants	5-47
5-5.	Infiltration rates with averages by source area for carbon-14	5-48
5-6.	Infiltration rates with averages by source area for volatile organic compounds.....	5-49
5-7.	Horizontal domain for remedial investigation and feasibility study vadose zone flow and transport	5-60
5-8.	Horizontal discretization for the vadose zone model domain	5-61
5-9.	Kriged ground surface elevation (feet above mean sea level) for the second-level refined grid.....	5-62
5-10.	Kriged thickness (feet) of surficial sediment for the second-level refined grid.....	5-63
5-11.	Kriged surface (feet above mean sea level) of the A-B interbed for the second-level refined grid.....	5-64
5-12.	Kriged thickness (feet) of the A-B interbed for the second-level refined grid	5-65
5-13.	Kriged surface (feet above mean sea level) of the B-C interbed for the first-level refined grid.....	5-66
5-14.	Kriged thickness (feet) of the B-C interbed for the first-level refined grid	5-67
5-15.	Kriged surface (feet above mean sea level) of the C-D interbed for the base grid	5-68
5-16.	Kriged thickness (feet) of the C-D interbed for the base grid.....	5-69
5-17.	Southwest views of base grid (A), first-level refined grid (B), and second-level refined grid (C) beneath the Subsurface Disposal Area showing vertical conformable gridding	5-71
5-18.	Kriged permeability (millidarcy) for the B-C and C-D interbeds.....	5-74
5-19.	Kriged porosity for the B-C and C-D interbeds	5-75
5-20.	Maximum simulated porosity for the B-C interbed	5-76
5-21.	Spatially variable infiltration assignment for the model domain inside the Subsurface Disposal Area.....	5-77
5-22.	Locations of additional water supplied by the 1962, 1969, and 1982 flooding events in the Subsurface Disposal Area in the second-level refined grid	5-78

FIGURES (continued)

5-23.	Initial-condition simulation showing the time history of water saturation in the C-D interbed beneath the Subsurface Disposal Area.....	5-79
5-24.	Maximum interbed water saturations for the base-case remedial investigation and feasibility study model.....	5-81
5-25.	Maximum interbed vertical water flux (cm/year) for the base-case remedial investigation and feasibility study model	5-83
5-26.	Remedial investigation and baseline risk assessment model domain with interpolated fall 2003 water table contours (feet)	5-88
5-27.	Permeability zones in the extended remedial investigation and baseline risk assessment aquifer model domain (values shown in millidarcy)	5-89
5-28.	Contours of simulated water levels (feet) for the base aquifer model domain and water level measurements at indicated wells from 2003	5-90
5-29.	Simulated groundwater average linear velocities (meters/year) for the first-level refined grid in the aquifer domain that matches the vadose zone model domain	5-91
5-30.	Simulated groundwater average linear velocities (meters/year) for the Ancillary Basis for Risk Analysis portion of the base aquifer model domain	5-92
5-31.	Simulated groundwater average linear velocities (meter/year) for the first-level refined grid in the aquifer domain, compared to interpreted aquifer flow directions, as a function of time	5-93
5-32.	Time-history comparison of simulated and observed concentrations for uranium-238 in the lysimeters at Wells PA01, PA02, W08, W98-4, and W25	5-96
5-33.	Time-history comparison of simulated and observed concentrations for uranium-238 in the lysimeters at Well W23.....	5-97
5-34.	Locations of cross sections in the second-level refined grid vadose zone domain.....	5-98
5-35.	Cross section showing simulated uranium-238 aqueous concentrations in Calendar Year 2004	5-99
5-36.	Cross section showing simulated uranium-238 aqueous concentrations in Calendar Year 2004	5-99
5-37.	Cross section showing simulated uranium-238 aqueous concentrations in Calendar Year 2004	5-100
5-38.	Time-history comparison of simulated and observed concentrations for technetium-99 in the lysimeters at Well W23.....	5-101

FIGURES (continued)

5-39.	Cross section showing simulated technetium-99 aqueous concentrations in Calendar Year 2004	5-102
5-40.	Time-history comparison of simulated and observed concentrations for nitrate in Lysimeters PA02-L16 and W25-L08.....	5-103
5-41.	Time-history comparison of simulated and observed concentrations for uranium-238 in lysimeters in the 35 to 250-ft depth interval	5-104
5-42.	Time-history comparison of simulated and observed concentrations for technetium-99 in the lysimeters in the 35 to 250-ft depth interval	5-105
5-43.	Time-history comparison of simulated and observed concentrations for nitrate in lysimeters in the 35 to 250-ft depth interval	5-106
5-44.	Comparison of simulated and observed nitrate concentration time histories for aquifer monitoring wells near the Subsurface Disposal Area.....	5-108
5-45.	Simulated and observed nitrate concentrations superimposed onto monitoring locations near the Radioactive Waste Management Complex	5-110
5-46.	Simulated aquifer nitrate concentrations (mg/L) for the year 2004 for the refined aquifer domain	5-111
5-47.	Simulated aquifer nitrate concentrations (mg/L) for the year 2004 for the base aquifer domain	5-112
5-48.	Simulated aquifer nitrate concentration profiles beneath the Subsurface Disposal Area	5-114
5-49.	Simulated aquifer nitrate concentrations (mg/L) for north-south cross sections through the location of maximum simulated concentration at times corresponding to profiles shown in Figure 5-48	5-115
5-50.	Time history of the simulated nitrate flux from the vadose zone simulation at the grid location profiled in Figure 5-48	5-116
5-51.	Comparison of simulated and observed chromium concentration time histories for aquifer monitoring wells near the Subsurface Disposal Area	5-118
5-52.	Comparison of simulated and observed iodine-129 concentration time histories for aquifer monitoring wells near the Subsurface Disposal Area	5-120
5-53.	Comparison of simulated and observed technetium-99 concentration time histories for aquifer monitoring wells near the Subsurface Disposal Area	5-122
5-54.	Comparison of simulated and observed americium-241 concentration time histories for aquifer monitoring wells near the Subsurface Disposal Area	5-124

FIGURES (continued)

5-55.	Comparison of simulated and observed neptunium-237 concentration time histories for aquifer monitoring wells near the Subsurface Disposal Area	5-126
5-56.	Comparison of simulated and observed plutonium-238 concentration time histories for aquifer monitoring wells near the Subsurface Disposal Area	5-128
5-57.	Comparison of simulated and observed plutonium-239 concentration time histories for aquifer monitoring wells near the Subsurface Disposal Area	5-130
5-58.	Simulated aquifer carbon-14 concentration profiles beneath the Subsurface Disposal Area.....	5-135
5-59.	Simulated aquifer uranium-238 concentration profiles beneath the Subsurface Disposal Area.....	5-136
5-60.	Comparison of base case and upper-bound inventory maximum simulated concentration anywhere in the aquifer for uranium-238, carbon-14, and nitrate	5-139
5-61.	Comparison of the base case and the no-B-C-interbed maximum simulated concentrations anywhere in the aquifer for uranium-238, carbon-14, and nitrate	5-141
5-62.	Comparison of base case and high infiltration inside the Subsurface Disposal Area maximum simulated concentration anywhere in the aquifer for uranium-238, carbon-14, and nitrate	5-142
5-63.	Maximum simulated water saturation in the B-C and C-D interbeds for the high-infiltration rate of 23 cm/year everywhere inside the Subsurface Disposal Area	5-143
5-64.	Comparison of the base case and Pit 4 inventory not removed and no beryllium block grouting maximum simulated concentration anywhere in the aquifer for uranium-238 and carbon-14	5-145
5-65.	Comparison of base case and low background infiltration maximum simulated concentration anywhere in the aquifer for uranium-238, carbon-14, and nitrate.....	5-146
5-66.	Comparison of base case and no low-permeability region in aquifer maximum simulated concentration anywhere in the aquifer for uranium-238, carbon-14, and nitrate.....	5-148
5-67.	Comparison of base case and low infiltration inside the Subsurface Disposal Area maximum simulated concentration anywhere in the aquifer for uranium-238, carbon-14, and nitrate	5-149
5-68.	Comparison of the base case and the no sorption in the interbeds maximum simulated concentration anywhere in the aquifer along the INL Site boundary and at the extreme southern extent of the model domain for plutonium-239 and plutonium-240	5-150
5-69.	Combined sensitivity results for maximum simulated concentration anywhere in the aquifer for uranium-238, carbon-14, and nitrate.....	5-152

FIGURES (continued)

5-70.	Comparison of simulated and measured carbon tetrachloride vapor concentration vertical profiles for select vapor monitoring wells near the Subsurface Disposal Area	5-160
5-71.	Comparison of simulated and measured carbon tetrachloride vapor concentration time histories for select vapor monitoring ports near the Subsurface Disposal Area through the year 1995.....	5-162
5-72.	Time-history comparison of simulated and measured carbon tetrachloride concentrations in the aquifer at wells in and around the Subsurface Disposal Area through 2005	5-163
5-73.	Time history of measured and simulated carbon tetrachloride concentrations in the aquifer at wells in and around the Subsurface Disposal Area	5-165
5-74.	Time-history comparison of simulated carbon tetrachloride mass flux to the aquifer, with and without a surface barometric pressure fluctuation	5-166
5-75.	Maximum simulated aquifer carbon-14 concentration, anywhere in the simulation domain, at a depth of 12 m, with and without surface barometric pressure fluctuations.....	5-168
5-76.	Maximum simulated concentration anywhere in the aquifer, with and without gaseous-phase partitioning in the vadose zone transport model	5-169
5-77.	Time history of simulated and observed carbon-14 aqueous-phase concentrations at Well USGS-92	5-170
5-78.	DOSTOMAN biotic modeling.....	5-174
6-1.	Human health conceptual site model	6-16
6-2.	Total carcinogenic risks over all pathways for chemical and radiological contaminants of potential concern for the hypothetical current and future residential exposure scenarios	6-43
6-3.	Total carcinogenic risks over all pathways for chemical and radiological contaminants of potential concern for hypothetical current and future occupational exposure scenarios	6-44
6-4.	Americium-241 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-46
6-5.	Carbon-14 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-46
6-6.	Cesium-137 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-47
6-7.	Iodine-129 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-47
6-8.	Lead-210 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-48

FIGURES (continued)

6-9.	Plutonium-239 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-48
6-10.	Plutonium-240 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-49
6-11.	Radium-226 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-49
6-12.	Radium-228 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-50
6-13.	Strontium-90 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-50
6-14.	Technetium-99 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-51
6-15.	Thorium-228 carcinogenic risks for hypothetical future residential scenario exposure pathways	6-51
6-16.	Carbon tetrachloride carcinogenic risks for hypothetical future residential scenario exposure pathways	6-52
6-17.	Carbon tetrachloride hazard index for hypothetical future residential scenario exposure pathways	6-52
6-18.	1,4-Dioxane carcinogenic risks for hypothetical future residential scenario exposure pathways	6-53
6-19.	Nitrate hazard index for hypothetical future residential scenario exposure pathways.....	6-53
6-20.	Cumulative groundwater ingestion risk isopleths for radionuclides at the end of the simulated 100-year institutional control period for the refined aquifer grid.....	6-58
6-21.	Cumulative groundwater ingestion risk isopleths for radionuclides at the end of the simulated 100-year institutional control period for the regional base aquifer grid.....	6-59
6-22.	Peak cumulative groundwater ingestion risk isopleths for volatile organic compounds for the refined aquifer grid.....	6-60
6-23.	Peak cumulative groundwater ingestion hazard index isopleths for the refined aquifer grid	6-60
6-24.	Peak cumulative groundwater ingestion risk isopleths for radionuclides (excluding technetium-99) for the refined aquifer grid.....	6-61
6-25.	Simulated 10,000-year groundwater ingestion risk for contaminants that peak after 1,000 years	6-62

FIGURES (continued)

6-26.	Total peak groundwater risk isopleths at the end of the 10,000-year groundwater simulation period for the local refined grid	6-64
6-27.	Total peak groundwater risk isopleths at the end of the 10,000-year groundwater simulation period for the regional refined grid	6-65
6-28.	Total carcinogenic risk for Group 1 contaminants for hypothetical future residential exposure pathways for the 1,000-year simulation period	6-68
6-29.	Simulated maximum groundwater concentrations for Group 1 contaminants at the Subsurface Disposal Area boundary for the 10,000-year simulation period	6-68
6-30.	Simulated groundwater ingestion risk for Group 1 contaminants at the Subsurface Disposal Area boundary for the 10,000-year simulation period	6-69
6-31.	Simulated maximum groundwater concentrations for Group 1 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period	6-69
6-32.	Simulated maximum groundwater ingestion risk for Group 1 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period	6-70
6-33.	Simulated soil concentrations for Group 1 contaminants	6-70
6-34.	Simulated total carcinogenic risk for Group 1 contaminants for hypothetical future occupational scenario exposure pathways	6-71
6-35.	Total carcinogenic risk for Group 2 contaminants for hypothetical future residential scenario exposure pathways for the 1,000-year simulation period	6-72
6-36.	Simulated maximum groundwater concentrations for Group 2 contaminants at the Subsurface Disposal Area boundary for the 10,000-year simulation period	6-72
6-37.	Simulated groundwater ingestion risk for Group 2 contaminants at the Subsurface Disposal Area boundary for the 10,000-year simulation period	6-73
6-38.	Simulated maximum groundwater concentrations for Group 2 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period	6-73
6-39.	Simulated maximum groundwater ingestion risk for Group 2 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period	6-74
6-40.	Simulated soil concentrations for Group 2 contaminants	6-74
6-41.	Simulated risk for a hypothetical future occupational scenario for Group 2 contaminants	6-75
6-42.	Total carcinogenic risk for Group 3 contaminants for hypothetical future residential scenario exposure pathways for the 1,000-year simulation period	6-76

FIGURES (continued)

6-43.	Simulated maximum groundwater concentrations for Group 3 contaminants at the Subsurface Disposal Area boundary for the 10,000-year simulation period	6-76
6-44.	Groundwater ingestion risk at the Subsurface Disposal Area boundary for Group 3 contaminants for the 10,000-year simulation period	6-77
6-45.	Simulated maximum groundwater concentrations for Group 3 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period	6-77
6-46.	Simulated maximum groundwater ingestion risk for Group 3 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period	6-78
6-47.	Simulated soil concentrations for Group 3 contaminants	6-78
6-48.	Simulated risk for a hypothetical future occupational scenario for Group 3 contaminants	6-79
6-49.	Total carcinogenic risk for Group 4 contaminants for hypothetical future residential exposure pathways for the 1,000-year simulation period	6-80
6-50.	Simulated maximum groundwater concentrations for Group 4 contaminants at the Subsurface Disposal Area boundary for the 10,000-year simulation period	6-80
6-51.	Groundwater ingestion risk at the Subsurface Disposal Area boundary over 10,000 years for Group 4 contaminants	6-81
6-52.	Simulated maximum groundwater concentrations for Group 4 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period	6-81
6-53.	Simulated maximum groundwater ingestion risk for Group 4 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period	6-82
6-54.	Simulated soil concentrations for Group 4 contaminants	6-82
6-55.	Simulated risk for the hypothetical future occupational scenario for Group 4 contaminants	6-83
6-56.	Total carcinogenic risk for Group 5 contaminants for hypothetical future residential scenario exposure pathways for the 1,000-year simulation period	6-84
6-57.	Simulated maximum groundwater concentrations for Group 5 contaminants at the Subsurface Disposal Area boundary for the 10,000-year simulation period	6-84
6-58.	Groundwater ingestion risk at the Subsurface Disposal Area boundary for the 10,000-year simulation period for Group 5 contaminants	6-85
6-59.	Simulated maximum groundwater concentrations for Group 5 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period	6-85

FIGURES (continued)

6-60.	Simulated maximum groundwater ingestion risk for Group 5 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period.....	6-86
6-61.	Simulated soil concentrations for Group 5 contaminants	6-86
6-62.	Occupational scenario risk for Group 5 contaminants for the 1,000-year simulation period	6-87
6-63.	Total carcinogenic risk for Group 6 contaminants for hypothetical future residential scenario exposure pathways for the 1,000-year simulation period	6-88
6-64.	Simulated maximum groundwater concentrations for Group 6 contaminants at the Subsurface Disposal Area boundary for the 10,000-year simulation period	6-88
6-65.	Groundwater ingestion risk at the Subsurface Disposal Area boundary for the 10,000-year simulation period for Group 6 contaminants	6-89
6-66.	Simulated maximum groundwater concentrations for Group 6 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period.....	6-89
6-67.	Simulated maximum groundwater ingestion risk for Group 6 contaminants at the southern boundary of the Idaho National Laboratory Site for the 10,000-year simulation period.....	6-90
6-68.	Simulated soil concentrations for Group 6 contaminants	6-90
6-69.	Occupational scenario risk for Group 6 contaminants for the 1,000-year simulation period	6-91
6-70.	Total carcinogenic risk for Group 8 contaminant for hypothetical future residential scenario exposure pathways for the 1,000-year simulation period.....	6-92
6-71.	Simulated maximum groundwater concentrations for Group 8 contaminant at the Subsurface Disposal Area boundary over 10,000 years	6-92
6-72.	Groundwater ingestion risk for the 10,000-year simulation period for Group 8 contaminant.....	6-93
6-73.	Simulated maximum groundwater concentrations for Group 8 contaminant over 10,000 years at the southern boundary of the Idaho National Laboratory Site.....	6-93
6-74.	Simulated maximum groundwater ingestion risk for Group 8 contaminant over 10,000 years at the southern boundary of the Idaho National Laboratory Site.....	6-94
6-75.	Simulated occupational scenario risk for the Group 8 contaminant	6-94
6-76.	Total carcinogenic risk for Group 9 contaminants for hypothetical future residential exposure pathways for the 1,000-year simulation period	6-95
6-77.	Simulated soil concentrations for Group 9 contaminants	6-96
6-78.	Simulated occupational scenario risk for Group 9 contaminants.....	6-96

FIGURES (continued)

6-79.	Total hazard index for the Group 10 contaminant for hypothetical future residential scenario exposure pathways for the 1,000-year simulation period.....	6-97
6-80.	Simulated maximum groundwater concentrations at the Subsurface Disposal Area boundary for Group 10 contaminant over 10,000 years	6-98
6-81.	Groundwater ingestion hazard index at the Subsurface Disposal Area boundary for Group 10 contaminant for the 10,000-year simulation period.....	6-98
6-82.	Simulated maximum groundwater concentrations for Group 10 contaminant over 10,000 years at the southern boundary of the Idaho National Laboratory Site.....	6-99
6-83.	Simulated maximum groundwater ingestion hazard index for Group 10 contaminant over 10,000 years at the southern boundary of the Idaho National Laboratory Site.....	6-99
6-84.	Simulated occupational scenario hazard index for Group 10 contaminant.....	6-100
6-85.	Total carcinogenic risk for Group 11 contaminants for hypothetical future residential exposure pathways for the 1,000-year simulation period	6-101
6-86.	Total hazard index for Group 11 contaminants for hypothetical future residential scenario exposure pathways for the 1,000-year simulation period	6-101
6-87.	Simulated maximum groundwater concentrations at the Subsurface Disposal Area boundary for Group 11 contaminants over 1,000 years.....	6-102
6-88.	Groundwater ingestion risk at the Subsurface Disposal Area boundary for Group 11 contaminants over 1,000 years.....	6-102
6-89.	Groundwater ingestion hazard index at the Subsurface Disposal Area boundary for Group 11 contaminants over 1,000 years.....	6-103
6-90.	Simulated maximum groundwater concentrations for Group 11 contaminants at the southern boundary of the Idaho National Laboratory Site over 1,000 years	6-103
6-91.	Simulated maximum groundwater ingestion risk for Group 11 contaminants at the southern boundary of the Idaho National Laboratory Site over 1,000 years	6-104
6-92.	Simulated maximum groundwater ingestion hazard index for Group 11 contaminants at the southern boundary of the Idaho National Laboratory Site over 1,000 years.....	6-104
6-93.	Simulated occupational scenario risk for Group 11 contaminants.....	6-105
6-94.	Simulated occupational scenario hazard index for Group 11 contaminants	6-105
6-95.	Comparison of estimated all-pathways risk at the Subsurface Disposal Area boundary for best-estimate and upper-bound inventories sensitivity case	6-117

FIGURES (continued)

6-96.	Comparison of estimated all-pathways hazard index at the Subsurface Disposal Area boundary for best-estimate and upper-bound inventories sensitivity case.....	6-117
6-97.	Groundwater ingestion risk from radionuclides comparing the base case to the reduced background infiltration sensitivity case	6-120
6-98.	Comparison of estimated technetium-99 and iodine-129 groundwater ingestion risk for the reduced background infiltration sensitivity case.....	6-120
6-99.	Comparison of estimated nitrate groundwater ingestion hazard quotient for the reduced background infiltration sensitivity case	6-121
6-100.	Reduced infiltration sensitivity case (peak groundwater ingestion) inside the Subsurface Disposal Area, with and without technetium-99 and iodine-129.....	6-122
6-101.	High infiltration inside the Subsurface Disposal Area sensitivity case shown on a detailed risk scale, with and without technetium-99 and iodine-129.....	6-123
6-102.	Comparison of estimated technetium-99 and iodine-129 groundwater ingestion risk for the sensitivity case of high infiltration inside the Subsurface Disposal Area	6-123
6-103.	Comparison of estimated nitrate groundwater ingestion hazard quotient for the sensitivity case of high infiltration inside the Subsurface Disposal Area	6-124
6-104.	Comparison of estimated carbon-14 groundwater ingestion risk for the sensitivity case of high infiltration inside the Subsurface Disposal Area	6-124
6-105.	No B-C interbed sensitivity case (groundwater ingestion risk), with and without technetium-99 and iodine-129	6-125
6-106.	Comparison of estimated technetium-99 and iodine-99 groundwater ingestion risk for the B-C interbed gaps sensitivity case	6-126
6-107.	Comparison of estimated nitrate groundwater ingestion hazard quotient for the B-C interbed gaps sensitivity case.....	6-126
6-108.	Comparison of groundwater ingestion risk on a detailed scale for the no-grout and no-retrieval sensitivity case, with and without technetium-99 and iodine-129.....	6-127
6-109.	Comparison of estimated technetium-99 and iodine-129 groundwater ingestion risk for the no-grout and no-retrieval sensitivity case.....	6-128
6-110.	Comparison of estimated carbon-14 groundwater ingestion risk for the no-grout and no-retrieval sensitivity case.....	6-128
6-111.	Comparison of estimated uranium-238 groundwater ingestion risk for the no-grout and no-retrieval sensitivity case.....	6-129
6-112.	Groundwater ingestion risk for the no-retrieval and no-grout sensitivity case.....	6-129

FIGURES (continued)

6-113. Comparison of surface exposure pathway risk for the no-retrieval sensitivity case.....	6-130
6-114. Radionuclide groundwater ingestion risk for the no-low-permeability zone sensitivity case.....	6-131
6-115. Total groundwater ingestion risk for the no-low-permeability zone sensitivity case, with and without technetium-99 and iodine-129	6-131
6-116. Carbon tetrachloride groundwater ingestion risk for the no-low-permeability zone sensitivity case	6-132
6-117. Groundwater ingestion risk at the southern boundary of the Idaho National Laboratory Site for the no-sorption sensitivity case compared to the base case for plutonium-239	6-133
6-118. Groundwater ingestion risk at the southern boundary of the Idaho National Laboratory Site for the no-sorption sensitivity case compared to the base case for plutonium-240	6-133
6-119. Conceptual model for the inadvertent intruder scenario represented by a well driller completing an agricultural well through buried waste.....	6-134
6-120. Location and breakdown of high-alpha waste for the intruder scenario.....	6-135
6-121. Location of high-gamma shipments used for the intruder scenario.....	6-140
6-122. Inadvertent intruder scenario represented by a well driller completing an agricultural well through buried waste.....	6-141
6-123. Surface soil pathways and exposure routes for ecological receptors in the Subsurface Disposal Area.....	6-166
6-124. Subsurface soil pathways and exposure routes for ecological receptors in the Subsurface Disposal Area.....	6-167
6-125. Ecological conceptual site model for the Subsurface Disposal Area.....	6-168
6-126. Total residential exposure scenario risk by exposure pathway for all radionuclides and nonradionuclides.....	6-181
6-127. Major contributors to external exposure risk	6-182
6-128. Major contributors to soil ingestion risk	6-182
6-129. Major contributors to crop ingestion risk.....	6-183
6-130. Major contributors to inhalation risk	6-183
6-131. Major contributors to volatile inhalation risk	6-184
6-132. Major contributors to groundwater ingestion risk.....	6-185

FIGURES (continued)

7-1.	Idaho National Laboratory Site.....	7-7
7-2.	Radioactive Waste Management Complex.....	7-9
7-3.	Recurring constituents in vadose zone lysimeters	7-13
7-4.	Radionuclides detected in core samples between 1971 and 2003.....	7-15
7-5.	Constituents in aquifer monitoring wells.....	7-16
7-6.	Eighteen source areas simulated in the source-release model	7-20
7-7.	Southwest views of base grid (A), first-level refined grid (B), and second-level refined grid (C) beneath the Subsurface Disposal Area showing vertical conformable gridding.....	7-21
7-8.	Combined sensitivity results for maximum simulated concentration anywhere in the aquifer for uranium-238, carbon-14, and nitrate.....	7-22
7-9.	Human health conceptual site model	7-24
7-10.	Total residential exposure scenario risk by exposure pathway for all radionuclides and nonradionuclides	7-26
7-11.	Major contributors to external exposure risk	7-26
7-12.	Major contributors to soil ingestion risk.....	7-27
7-13.	Major contributors to crop ingestion risk.....	7-27
7-14.	Major contributors to inhalation risk	7-28
7-15.	Volatile inhalation risk by contaminant.....	7-28
7-16.	Groundwater ingestion risk by contaminant.....	7-29
7-17.	Peak cumulative groundwater ingestion risk isopleths for radionuclides for the regional refined grid.....	7-35
7-18.	Peak cumulative groundwater ingestion risk isopleths for radionuclides for the aquifer refined grid.....	7-36
7-19.	Peak cumulative groundwater ingestion risk isopleths for volatile organic compounds	7-36
7-20.	Peak cumulative groundwater ingestion hazard index isopleths.....	7-37
7-21.	Groundwater ingestion risk for radionuclides, including and excluding technetium-99 and iodine-129	7-38
7-22.	Peak cumulative groundwater ingestion risk isopleths for radionuclides, excluding technetium-99	7-38

FIGURES (continued)

7-23.	Simulated 10,000-year groundwater ingestion risk for contaminants that peak after 1,000 years	7-41
7-24.	Peak groundwater risk isopleths for radionuclides at the end of the 10,000-year groundwater simulation period for the regional refined grid	7-42
7-25.	Peak cumulative groundwater risk isopleths for radionuclides at the end of the 10,000-year groundwater simulation period for the local refined grid	7-43

TABLES

2-1.	Names and common aliases for wells in the vicinity of the Radioactive Waste Management Complex	2-28
2-2.	Identifiers, depth, and lithology of advanced tensiometers at Radioactive Waste Management Complex	2-43
2-3.	Suction lysimeters monitored at the Radioactive Waste Management Complex	2-47
2-4.	Population estimates for counties and selected communities surrounding the Idaho National Laboratory Site.....	2-63
3-1.	Summary of Waste Area Group 7 collocated facilities.....	3-15
3-2.	Rocky Flats Plant production plants, operations, and types of material processed from 1953 to 1970	3-26
3-3.	Suspect drums shipped to the Idaho National Laboratory Site	3-29
3-4.	Comparison of two suspect drums	3-29
3-5.	Rocky Flats Plant plutonium isotopic levels in waste by average weight percent.....	3-30
3-6.	Typical isotopic concentrations in waste	3-30
3-7.	Economic discard limits for Fiscal Year 1969.....	3-31
3-8.	Average plutonium values for drums shipped in 1966 and 1967.....	3-31
3-9.	Organic waste accumulated over a 3-month period.....	3-32
3-10.	Plutonium discard limits for filter media in 1992.....	3-33
3-11.	Summary of filters shipped to the Idaho National Laboratory Site	3-34
3-12.	Summary of depleted uranium waste shipments to the Idaho National Laboratory Site	3-35
3-13.	Disposal summary of plutonium-contaminated material from the Rocky Flats Plant 903 Pad storage area	3-38
3-14.	Comparison of isotopic activity in grouted and ungrouted beryllium	3-63
3-15.	Dates of operation, primary waste generators, and areas and volumes of Subsurface Disposal Area trenches, including overburden	3-68
3-16.	Dates of operation, primary waste generators, and areas and volumes of Subsurface Disposal Area pits, including overburden.....	3-70
3-17.	Dates of operation, primary waste generators, and volumes of Subsurface Disposal Area soil vault rows, including overburden.....	3-71

TABLES (continued)

3-18.	Estimated soil-cover thicknesses	3-72
3-19.	Subsidence data for the Subsurface Disposal Area.....	3-75
3-20.	Operable units and sites in Waste Area Group 7	3-80
3-21.	Additional screening for surface exposure contaminants	3-110
3-22.	Screening-level risk estimates for mixed-fission-product isotopes	3-111
3-23.	Surface pathway risks for mixed-fission-product isotopes	3-112
3-24.	Review of qualitatively evaluated contaminants	3-113
3-25.	Iterative screening of quantitatively evaluated contaminants	3-116
3-26.	Comparison of upper-bound radionuclide inventory to minimum ecologically based screening levels.....	3-119
3-27.	Nonradionuclide ecological contaminants of potential concern	3-121
3-28.	Summary of geophysical surveys of the Subsurface Disposal Area (1989 to 2004)	3-123
3-29.	Minimum, maximum, and average soil-cover thickness for Pits 4, 6, and 10	3-129
3-30.	Clusters of probes in the western end of Pit 10 and the eastern end of Pit 4 supporting depleted uranium waste assessment.....	3-143
3-31.	Clusters of probes in the Organic Sludge Focus Area in the eastern end of Pit 4.....	3-149
3-32.	Clusters of probes supporting waste assessment of americium and neptunium in Pit 10	3-151
3-33.	Clusters of probes supporting uranium waste assessment in Pit 5	3-152
3-34.	Clusters of probes supporting activated metal assessment	3-157
3-35.	Clusters of probes in the waste zone moisture monitoring array at Pits 4 and 10	3-163
3-36.	Logging methods used to interpret vertical waste boundaries	3-166
3-37.	Estimates of overburden and waste zone thickness from Type A logging data.....	3-166
3-38.	Geologic and Environmental Probe System lysimeter information and sample volumes	3-167
3-39.	Summary of batch and column measurements of americium, plutonium, and uranium partition coefficients	3-176
3-40.	Summary of retardation and K_d values measured in column experiments	3-178
3-41.	Measured Freundlich and linear isotherm parameters for neptunium and uranium	3-180

TABLES (continued)

3-42.	Summary of the Advanced Test Reactor, Engineering Test Reactor, and Materials Test Reactor irradiated beryllium reflector waste buried in the Subsurface Disposal Area	3-191
3-43.	Summary of tritiated water activity (pCi of tritium per mL water) in soil-gas samples collected from Probes RWMC-2022 and-2023 at Soil Vault Row 20.....	3-196
3-44.	Summary of carbon-14 specific activity (pCi of carbon-14 per gram of carbon) in carbon dioxide in soil-gas samples collected from abandoned probes at Soil Vault Row 20	3-197
3-45.	Summary of carbon-14 specific activity (pCi of carbon-14 per gram of carbon) in carbon dioxide in soil-gas samples collected from probes at Soil Vault Row 20.....	3-197
4-1.	Background concentrations and comparison values for soil and water	4-20
4-2.	Summary by waste generator of best-estimate inventories (curies) of selected radionuclides at the time of disposal in the Subsurface Disposal Area	4-25
4-3.	Summary by waste generator of best-estimate inventories (grams) of selected chemicals buried in the Subsurface Disposal Area	4-27
4-4.	Radiological waste streams and best-estimate inventories (curies) at time of disposal.....	4-27
4-5.	Rocky Flats Plant plutonium-238, -239, and -240 waste streams and best-estimate inventories (curies) at time of disposal	4-38
4-6.	Nitrate and chromium waste streams and best-estimate inventories (grams) at time of disposal	4-39
4-7.	Volatile organic compound waste streams and best-estimate inventories (grams) at time of disposal	4-40
4-8.	Description of Type A probe logging tools	4-76
4-9.	Americium-241 detections in shallow (less than 35 ft) lysimeters	4-101
4-10.	Americium-241 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997	4-103
4-11.	Americium-241 detections in deep (greater than 140 ft) lysimeters since 1974.....	4-105
4-12.	Americium-241 detections in aquifer wells since October 1992	4-108
4-13.	Americium-241 detections in U.S. Geological Survey aquifer wells from 1972 through 1992	4-110
4-14.	Americium-241 detections in U.S. Geological Survey aquifer wells from 1993 through 2003	4-113
4-15.	Concentration ranges and detection frequencies of americium-241 in sampled media	4-115

TABLES (continued)

4-16.	Carbon-14 detections in shallow (less than 35 ft) lysimeters since 1997	4-117
4-17.	Carbon-14 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997	4-119
4-18.	Carbon-14 detections in deep (greater than 140 ft) lysimeters since 1997	4-121
4-19.	Carbon-14 detections in aquifer wells since 1994	4-128
4-20.	Concentration ranges and detection frequencies of carbon-14 in sampled media	4-130
4-21.	Cesium-137 detections and nondetections in Idaho National Laboratory and U.S. Geological Survey aquifer monitoring wells from 1972 through 2005	4-133
4-22.	Detection frequencies for cesium-137 in sampled media	4-135
4-23.	Chlorine-36 detections in shallow-depth (less than 35 ft) lysimeters since 2003	4-138
4-24.	Chlorine-36 detections in intermediate-depth (35 to 140 ft) lysimeters since 2003	4-138
4-25.	Chlorine-36 detections in deep (greater than 140 ft) lysimeters and perched water wells since 2003	4-139
4-26.	Chlorine-36 detections in aquifer wells since 2001	4-140
4-27.	Concentration ranges and detection frequencies of chlorine-36 in sampled media	4-142
4-28.	Concentration ranges and detection frequencies of tritium for sampled media	4-145
4-29.	Iodine-129 detections in shallow-depth (less than 35 ft) lysimeters since 1997	4-148
4-30.	Iodine-129 detections in aquifer wells since 1994	4-149
4-31.	Concentration ranges and detection frequencies of iodine-129 in sampled media	4-151
4-32.	Concentration ranges and detection frequencies of neptunium-237 in sampled media	4-156
4-33.	Plutonium-238 detections in shallow (less than 35 ft) lysimeters since 1997	4-161
4-34.	Plutonium-239/240 detections in shallow (less than 35 ft) lysimeters since 1997	4-163
4-35.	Plutonium-238 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997	4-164
4-36.	Plutonium-239/240 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997	4-165
4-37.	Plutonium-238 detections in deep (greater than 140 ft) lysimeters and perched water since 1972	4-167
4-38.	Plutonium-239/240 detections in deep (greater than 140 ft) lysimeters and perched water since 1972	4-169

TABLES (continued)

4-39.	Plutonium-238 detections in aquifer wells since October 1992.....	4-172
4-40.	Plutonium-239/240 detections in aquifer wells since October 1992	4-174
4-41.	Plutonium-238 detections in cosampled Wells M1S and M3S during September and October 2000.....	4-176
4-42.	Plutonium-238 detections in U.S. Geological Survey aquifer wells from 1972 through 1992	4-177
4-43.	Plutonium-238 detections in U.S. Geological Survey aquifer wells from 1993 through 2003	4-179
4-44.	Plutonium-239/240 detections in U.S. Geological Survey aquifer wells from 1972 through 1992	4-181
4-45.	Plutonium-239/240 detections in U.S. Geological Survey aquifer wells from 1993 through 2003	4-183
4-46.	Concentration ranges and detection frequencies of plutonium-238 in sampled media.....	4-190
4-47.	Concentration ranges and detection frequencies of plutonium-239/240 in sampled media	4-191
4-48.	Radium-226 detections in shallow (less than 35 ft) lysimeters since 1997	4-195
4-49.	Radium-226 detections in aquifer wells since 1996	4-196
4-50.	Concentration ranges and detection frequencies of radium-226 greater than background levels for sampled media	4-198
4-51.	Strontium-90 detections in shallow (less than 35 ft) lysimeters from 1997 to 2001	4-201
4-52.	Strontium-90 detections in aquifer wells from 1992 through 2004	4-202
4-53.	Strontium-90 detections in U.S. Geological Survey aquifer wells from 1972 through 1992	4-204
4-54.	Strontium-90 detections in U.S. Geological Survey aquifer wells from 1993 through April 2003.....	4-207
4-55.	Concentration ranges and detection frequencies of strontium-90 in sampled media.....	4-209
4-56.	Technetium-99 detections in shallow (less than 35 ft) lysimeters since 1997	4-211
4-57.	Technetium-99 detections in intermediate-depth (35 to 140 ft) lysimeters since 1996	4-212
4-58.	Technetium-99 detections in deep (greater than 140 ft) lysimeters and perched water since 1996	4-215
4-59.	Technetium-99 detections in aquifer wells since 1994	4-220

TABLES (continued)

4-60.	Detection frequencies for technetium-99 in sampled media.....	4-223
4-61.	Properties of uranium isotopes.....	4-225
4-62.	Radioactivity ratios for evaluating uranium data.....	4-226
4-63.	Typical isotopic composition of anthropogenic uranium (weight percent)	4-226
4-64.	Statistical characteristics of uranium isotope background concentrations in lysimeter samples at the Subsurface Disposal Area	4-231
4-65.	Detection rates for uranium-235 and uranium-238 from the gamma-logging tool.....	4-232
4-66.	Uranium-233/234 detections in shallow-depth (0 to 35 ft) lysimeters since 1997	4-234
4-67.	Uranium-235/236 detections in shallow-depth (less than 35 ft) lysimeters since 1997.....	4-236
4-68.	Uranium-238 detections in shallow-depth (less than 35 ft) lysimeters since 1997.....	4-238
4-69.	Uranium concentrations measured by inductively coupled plasma-mass spectrometry and alpha spectrometry to assess isotopic ratios	4-242
4-70.	Uranium-233/234 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997	4-243
4-71.	Uranium-235/236 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997	4-245
4-72.	Uranium-238 detections in intermediate-depth (35 to 140 ft) lysimeters since 1997	4-247
4-73.	Uranium-233/234 detections in deep (greater than 140 ft) lysimeters and perched water since 1997	4-253
4-74.	Uranium-235/236 detections in deep (greater than 140 ft) lysimeters and perched water since 1997	4-254
4-75.	Uranium-238 detections in deep (greater than 140 ft) lysimeters and perched water since 1997	4-255
4-76.	Uranium-233/234 detections in aquifer wells since 1998.....	4-258
4-77.	Uranium-235/236 detections in aquifer wells since 1998.....	4-259
4-78.	Uranium-238 detections in aquifer wells since 1998.....	4-260
4-79.	Concentration ranges and detection frequencies of uranium-233/234 results greater than background levels for sampled media since 1998	4-261
4-80.	Concentration ranges and detection frequencies of uranium-235/236 results greater than background levels for sampled media.....	4-262

TABLES (continued)

4-81.	Concentration ranges and detection frequencies of uranium-238 results greater than background levels for sampled media.....	4-263
4-82.	Nitrate detection frequencies for concentrations greater than background for sampled media.....	4-272
4-83.	Chromium detection frequencies of concentrations greater than background for sampled media.....	4-278
4-84.	Anions and metal with concentrations above background in Subsurface Disposal Area vadose zone soil moisture (lysimeter) and perched water	4-281
4-85.	Anion and cation concentrations greater than aquifer background levels	4-284
4-86.	Operable Unit 7-08 project remediation goals for carbon tetrachloride in soil gas	4-287
4-87.	Distribution of Series 743 waste drums and carbon tetrachloride mass after drum retrieval from Pits 11 and 12.....	4-288
4-88.	Maximum carbon tetrachloride vapor concentrations from Type B vapor probes	4-289
4-89.	Summary of carbon tetrachloride data collected from 1992 and 1993 surface flux chamber measurements.....	4-290
4-90.	Summary of carbon tetrachloride vapor concentration results from August 1992 TEM-series well samples.....	4-293
4-91.	Carbon tetrachloride data for perched water samples in Wells USGS-92, 8802D, and D10 at the Subsurface Disposal Area	4-301
4-92.	Maximum carbon tetrachloride concentrations in lysimeters	4-303
4-93.	Summary of carbon tetrachloride data from aquifer monitoring wells near the Subsurface Disposal Area.....	4-303
4-94.	Carbon tetrachloride detection frequencies for aqueous samples.....	4-307
4-95.	1,4-Dioxane results from waste zone lysimeter samples	4-309
4-96.	Summary of positive detections of methylene chloride in soil-gas samples collected near the Subsurface Disposal Area	4-311
4-97.	Summary of methylene chloride detections in the aquifer.....	4-312
4-98.	Methylene chloride detection frequencies for aqueous samples.....	4-312
4-99.	Maximum tetrachloroethylene vapor concentrations from Type B vapor probes	4-314
4-100.	Tetrachloroethylene data for perched water samples at the Subsurface Disposal Area.....	4-315

TABLES (continued)

4-101.	Tetrachloroethylene detection frequencies for aqueous samples	4-317
4-102.	Maximum trichloroethylene vapor concentrations from Type B vapor probes	4-319
4-103.	Trichloroethylene data for perched water samples at the Subsurface Disposal Area	4-320
4-104.	Trichloroethylene detection frequencies for aqueous samples	4-322
4-105.	Summary of environmental monitoring data collected for radionuclides in and around the Subsurface Disposal Area between 1976 and 1995	4-324
4-106.	Cross references to nature and extent sections for radionuclide ecological contaminants of potential concern.....	4-325
4-107.	Summary of environmental surveillance data collected for radionuclides in and around the Subsurface Disposal Area between 1972 and 1987	4-326
4-108.	Inorganic ecological contaminants of potential concern and soil sample analyses	4-327
4-109.	Summary of organic ecological contaminants of potential concern and soil sample analyses	4-328
5-1.	Contaminants evaluated in the remedial investigation and baseline risk assessment and the computer models used to assess them.....	5-11
5-2.	Radiological waste streams, best-estimate inventories (curies) at time of disposal, and baseline source-release information for Operable Unit 7-13/14	5-15
5-3.	Rocky Flats Plant plutonium-238, -239, and -240 waste streams, best-estimate inventories (curies) at time of disposal, and baseline source-release information for Operable Unit 7-13/14 modeling	5-26
5-4.	Nitrate and chromium waste streams, best-estimate inventories (grams) at time of disposal, and baseline source-release information for Operable Unit 7-13/14 modeling	5-28
5-5.	Volatile organic compound waste streams, best-estimate inventories (grams) at time of disposal, and baseline source-release information for Operable Unit 7-13/14 modeling	5-29
5-6.	Factors used to convert disposal quantity (grams) to amount of contaminant in the total waste stream to nitrate as total nitrogen.....	5-31
5-7.	Beryllium blocks buried in the Subsurface Disposal Area	5-34
5-8.	Contaminant groups for Operable Unit 7-13/14 simulations.....	5-36
5-9.	Source areas in the Subsurface Disposal Area implemented in the source-release model for all contaminants, except carbon-14	5-38

TABLES (continued)

5-10.	Carbon-14 source areas in the Subsurface Disposal Area implemented in the source-release model.....	5-38
5-11.	Activity (curies) of radionuclides (Groups 1 through 6 and 9) buried in the 18 simulated source areas, by simulation groups and waste stream types, for Subsurface Disposal Area modeling.....	5-41
5-12.	Mass (grams) of volatile organic compounds and nonradionuclides (Groups 10 and 11) buried in the 18 simulated source areas, by simulation groups, for Subsurface Disposal Area modeling.....	5-42
5-13.	Revised modeled activity (curies) of carbon-14 (Group 8) in beryllium blocks at time of grouting and at time of grout failure	5-42
5-14.	Revised modeled activity (curies) of radionuclides (Group 6) at time of grouting and at time of grout failure	5-43
5-15.	Activity (curies) of tritium and carbon-14 (Group 8) in beryllium blocks buried in the nine simulated source areas, by simulation groups, for Subsurface Disposal Area modeling.....	5-43
5-16.	Activity (curies) of radionuclides (Groups 1 through 6 and 9) in Pit 4 before and after the Accelerated Retrieval Project retrieval	5-45
5-17.	Mass (grams) of volatile organic compounds and nonradionuclides (Groups 10 and 11) in Pit 4 before and after the Accelerated Retrieval Project retrieval.....	5-46
5-18.	Parameterization of hydrologic properties and source of parameters for surficial sediment, A-B interbed, and fractured basalt	5-72
5-19.	Historical flooding volumes and application rates at the Subsurface Disposal Area.....	5-79
5-20.	Sediment distribution coefficients for Operable Unit 7-13/14 remedial investigation and feasibility study simulations	5-85
5-21.	Aqueous-phase tortuosity values for the remedial investigation and feasibility study model	5-87
5-22.	Comparison of aquifer model concentrations and observed concentrations with no adjustments for background concentrations.....	5-133
5-23.	Run-naming nomenclature.....	5-137
5-24.	Simulation group names and descriptions	5-138
5-25.	Volatile organic compound chemical and transport properties.....	5-155
5-26.	Final tortuosity values for material types defined and used in the volatile organic compound model.....	5-156

TABLES (continued)

5-27.	Fractional root distribution for individual plant species specific to the Idaho National Laboratory Site for the current scenario	5-176
5-28.	Fractional root distribution for individual plant species for the 100-plus-year scenario	5-177
5-29.	Estimated parameters for the uptake of plant species for the Subsurface Disposal Area for current and 100 to 200-plus-year scenarios.....	5-178
5-30.	Small animal density and burrowing parameters for the current scenario.....	5-180
5-31.	Burrow volume and fraction of volume excavated at depth by small animals for the current scenario.....	5-181
5-32.	Small animal density and burrowing parameters for the Subsurface Disposal Area 100-plus-year scenario	5-182
5-33.	Burrow volume and fraction of volume excavated at depth by small animals for the 100-plus-year scenario in undisturbed soil	5-184
5-34.	Summary of improvements in the remedial investigation and feasibility study models compared to the Interim Risk Assessment and Ancillary Basis for Risk Analysis models	5-186
6-1.	Simulated maximum soil and groundwater concentrations for contaminants of potential concern and associated decay-chain members.....	6-17
6-2.	Toxicity values for quantitatively evaluated noncarcinogenic contaminants of potential concern.....	6-27
6-3.	Toxicity values for quantitatively evaluated chemical carcinogens	6-28
6-4.	Half-lives, slope factors, and other data used to estimate carcinogenic risk for radionuclide contaminants of potential concern and associated decay-chain members	6-33
6-5.	Risk scenario summary	6-37
6-6.	Summary of peak estimated risks and hazard indexes for the 1,000-year simulation period for hypothetical current and future occupational exposure scenarios.....	6-40
6-7.	Summary of estimated risks and hazard indexes for the 1,000-year simulation period for a hypothetical future residential exposure scenario	6-41
6-8.	Comparison of maximum groundwater concentrations to maximum contaminant levels for the 1,000-year simulation period.....	6-56
6-9.	Comparison of maximum groundwater concentrations to maximum contaminant levels for the 10,000-year simulation period.....	6-64
6-10.	Human health uncertainty factors	6-111

TABLES (continued)

6-11.	Parametric sensitivity cases	6-115
6-12.	Best-estimate and upper-bound inventories used in the baseline risk assessment and sensitivity analysis	6-116
6-13.	Comparison of risk estimates and hazard indexes for the residential exposure pathway at the Subsurface Disposal Area boundary for the 1,000-year simulation period based on best-estimate and upper-bound inventories.....	6-118
6-14.	Total curies in selected high-alpha shipments and relative amounts of each isotope for the intruder scenario.....	6-135
6-15.	Evaluation and selection of a high-gamma location for the intruder scenario.....	6-137
6-16.	Curies in high-gamma shipments decayed to the year 2110.....	6-139
6-17.	Input parameters used in the intruder scenario	6-142
6-18.	Initial radionuclide inventory for the high-gamma location at 100 years from facility closure and waste activity and radionuclide soil concentrations	6-143
6-19.	Initial radionuclide inventory 100 years after closure of the facility and waste activity and radionuclide soil concentrations for the high-alpha location	6-144
6-20.	Risk-to-source ratios for each radionuclide, by pathway, for the high-gamma location	6-145
6-21.	Risk-to-source ratios for each radionuclide, by pathway, for the high-alpha location	6-146
6-22.	Risk to an inadvertent intruder drilling an irrigation well into the Subsurface Disposal Area at the high-gamma location.....	6-147
6-23.	Risk to an inadvertent intruder drilling an irrigation well into the Subsurface Disposal Area at the high-alpha location.....	6-148
6-24.	Species observed in habitats in and around the Waste Area Group 7 assessment area	6-151
6-25.	Threatened or endangered species, sensitive species, and species of concern that may be found on the Idaho National Laboratory Site.....	6-153
6-26.	Habitat rating conventions for sites of concern evaluated in the Operable Unit 7-13/14 ecological risk assessment	6-156
6-27.	Summary of biological field survey for Waste Area Group 7	6-157
6-28.	Waste Area Group 7 ecological contaminants of potential concern retained for evaluation in the ecological risk assessment	6-158
6-29.	Comparison of estimated surface and subsurface soil concentrations to ecologically based screening levels for radionuclides.....	6-160

TABLES (continued)

6-30.	Comparison of estimated surface and subsurface soil concentrations to ecologically based screening levels for nonradionuclides.....	6-161
6-31.	Simulated soil concentrations for ecological contaminants of potential concern	6-164
6-32.	Receptors selected for analysis in the Waste Area Group 7 ecological risk assessment	6-169
6-33.	Exposure routes and ecological receptors modeled for surface and subsurface soil pathways	6-169
6-34.	Species exposure model parameters	6-170
6-35.	Summary of radiological contaminants of potential concern evaluated in the ecological risk assessment.....	6-173
6-36.	Summary of nonradiological contaminants of potential concern evaluated in the ecological risk assessment.....	6-173
6-37.	Hazard quotients for internal and external radiological exposures from surface soil for the current scenario.....	6-174
6-38.	Hazard quotients for internal and external radiological exposures from subsurface soil for the current scenario	6-175
6-39.	Hazard quotients for internal and external radiological exposures from subsurface soil for the 100-year scenario	6-175
6-40.	Hazard quotients for exposures to nonradiological contaminants in subsurface soil for the current scenario.....	6-177
6-41.	Hazard quotients for internal and external radiological exposure from surface soil for the 100-year scenario	6-178
6-42.	Hazard quotients for exposures to nonradiological contaminants in subsurface soil for the 100-year scenario	6-179
6-43.	Contaminants not specifically evaluated in the ecological risk assessment.....	6-179
7-1.	Primary radionuclide contaminants of concern based on 1,000-year future residential scenario peak risk estimates and groundwater concentrations.....	7-33
7-2.	Nonradionuclide contaminants of concern based on 1,000-year future residential scenario peak risk estimates and groundwater concentrations.....	7-34
7-3.	Original waste generators and general locations of primary contaminants of concern in the Subsurface Disposal Area	7-39
7-4.	Secondary radionuclide contaminants of concern based on 10,000-year future residential scenario groundwater ingestion peak risk estimates and groundwater concentrations.....	7-40

ACRONYMS

ABRA	Ancillary Basis for Risk Analysis
ARA	Auxiliary Reactor Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
COC	contaminant of concern
DEQ	(Idaho) Department of Environmental Quality
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy Idaho Operations Office
EDTA	ethylenediaminetetraacetic acid
EPA	U.S. Environmental Protection Agency
FFA/CO	Federal Facility Agreement and Consent Order
FY	fiscal year
GEOPS	Geologic and Environmental Probe System
HEPA	high-efficiency particulate air
ICP	Idaho Cleanup Project
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology Engineering Center
IRA	Interim Risk Assessment
LLW	low-level waste
MCL	maximum contaminant level
NRF	Naval Reactors Facility
OCVZ	Organic Contamination in the Vadose Zone
RBC	risk-based concentration (for soil)
RCRA	Resource Conservation and Recovery Act
RI/BRA	remedial investigation and baseline risk assessment
RI/FS	remedial investigation and feasibility study
ROD	record of decision
RTC	Reactor Technology Complex
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SVR	soil vault row
TAN	Test Area North
TRU	transuranic
TSA	Transuranic Storage Area
USGS	U.S. Geological Survey
VOC	volatile organic compound
WIPP	Waste Isolation Pilot Plant

CONTENTS

1.	INTRODUCTION.....	1-3
1.1	Purpose	1-3
1.2	Scope	1-3
1.3	Schedule	1-4
1.4	Regulatory Background.....	1-4
1.5	Report Organization	1-8
1.6	References	1-8

FIGURES

1-1.	Idaho National Laboratory Site.....	1-6
1-2.	Radioactive Waste Management Complex	1-7

1. INTRODUCTION

Site characteristics and estimated cumulative risks associated with Operable Unit 7-13/14 at the Idaho National Laboratory (INL) Site^a are presented in this remedial investigation and baseline risk assessment (RI/BRA). The RI/BRA assesses potential risk to human health and the environment in the absence of any further remedial action at the INL Radioactive Waste Management Complex (RWMC). The RI/BRA focuses almost exclusively on the Subsurface Disposal Area (SDA), a radioactive waste landfill within RWMC.

Operable Unit 7-13/14 is defined as the comprehensive remedial investigation and feasibility study (RI/FS) for RWMC. The RI/FS is being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC § 9601 et seq., 1980) under framework provided in the INL-specific Federal Facility Agreement and Consent Order (FFA/CO) (DOE-ID 1991). This RI/BRA is identified as an FFA/CO primary document (DOE 2002) and was prepared in accordance with U.S. Environmental Protection Agency (EPA) RI/FS guidance (EPA 1988).

Analysis presented in this report evaluates baseline risk (i.e., risk to human health and the environment in the hypothetical absence of any remedial action). The human health risk assessment identifies 18 primary and eight secondary contaminants of concern (COCs) for Operable Unit 7-13/14 for a total of 26 COCs (i.e., 20 radionuclides and six chemicals). Primary COCs are identified based on risk and simulated groundwater concentrations within a 1,000-year timeframe, while secondary COCs are identified based on simulated groundwater ingestion risk within 10,000 years. Primary COCs are Am-241, C-14, Cs-137, I-129, Pb-210, Pu-239, Pu-240, Ra-226, Ra-228, Sr-90, Tc-99, Th-228, carbon tetrachloride, 1,4-dioxane, methylene chloride, nitrate, tetrachloroethylene, and trichloroethylene. Secondary COCs are Ac-227, Np-237, Pa-231, U-233, U-234, U-235, U-236, and U-238. The ecological risk assessment identifies 10 radionuclides and three chemical ecological COCs: Am-241, Cs-137, Pu-238, Pu-239, Pu-240, Pu-241, Ra-226, Sr-90, U-234, U-238, beryllium, cadmium, and lead. Site characteristics and risk assessment details that underlie identification of these COCs are presented in the body of this report.

1.1 Purpose

This RI/BRA will provide the U.S. Department of Energy (DOE), the Idaho Department of Environmental Quality (DEQ), and the EPA with a basis for determining whether additional remedial action at RWMC is necessary. Information in this RI/BRA will support future risk management decisions for Waste Area Group 7 under CERCLA and the FFA/CO.

1.2 Scope

This RI/BRA incorporates relevant information from previous investigations and studies to assess risk conducted for Waste Area Group 7. The evaluation is cumulative and comprehensive, meaning that additive risks for all contaminants and exposure pathways were considered, and that all sources of risk at the SDA were analyzed to evaluate the overall risk potential.

a. In 2005, the Idaho National Engineering and Environmental Laboratory was renamed the INL Site, and management was split into two contracts: INL and Idaho Cleanup Project (ICP). The INL contract is managed by Battelle Energy Alliance and includes reactor design and development, nonnuclear energy development, materials testing and evaluation, and national security. The ICP contract is managed by CH2M-WG Idaho, LLC, and includes operational safety, radioactive waste management, and environmental restoration.

Primary elements of RI/BRA scope include:

- Assessing the nature and extent of contamination associated with Waste Area Group 7
- Evaluating current and future cumulative and comprehensive risks posed by Waste Area Group 7 to identify human health and environmental COCs.

The RWMC comprises (1) the SDA, which contains buried waste; (2) the Transuranic Storage Area (TSA), which contains waste stored above ground; and (3) an administration and operations area, with various support facilities. Quantitative analysis in this RI/BRA is limited to waste buried in the SDA. Risk potential associated with the TSA and support facilities will be evaluated in the future, after disposition of all stored waste is complete and the TSA is closed.

1.3 Schedule

Signing agencies of the FFA/CO (i.e., DOE, DEQ, and EPA) have modified scope and schedule for Operable Unit 7-13/14 several times since the FFA/CO was finalized in 1991. Modifications were predicated on the magnitude, complexity, and duration of the project; agreements to accommodate modified scope and schedule for the Operable Unit 7-10 interim action for Pit 9 (DOE-ID 1998a; DOE 2002); and a non-time-critical removal action to retrieve waste from Pit 4 (DOE 2004).

Originally, scope and schedule for Operable Unit 7-13/14 were outlined in the first Scope of Work (Huntley and Burns 1995), and details were developed in the original Operable Unit 7-13/14 RI/FS Work Plan (Becker et al. 1996). In 1997, DOE, DEQ, and EPA collaborated to revise the Scope of Work (INEEL 1997) and to develop the first Addendum to the Work Plan (DOE-ID 1998b). The schedule for delivering the draft RI/FS for DEQ and EPA review under the FFA/CO was modified from September 1997 to March 2002.

The Operable Unit 7-13/14 schedule was extended again to accommodate additional changes related to the Pit 9 interim action, in accordance with the April 16, 2002, Agreement to Resolve Disputes (DOE 2002). As a result of the agreement, the draft RI/BRA for Operable Unit 7-13/14 was reclassified from a secondary to a primary document under the FFA/CO and scheduled for submittal to DEQ and EPA with an enforceable deadline of August 2005. The enforceable deadline for the associated draft feasibility study, also a primary document, was rescheduled to December 2005. The Second Revision to the Scope of Work (Holdren and Broomfield 2003) and the Second Addendum to the Work Plan (Holdren and Broomfield 2004) were developed through collaboration among DOE, DEQ, and EPA to document the revised schedule and to modify scope for Operable Unit 7-13/14.

The most recent schedule extension was formalized by DOE, DEQ, and EPA to delay the Operable Unit 7-13/14 RI/FS while proceeding with retrieval of targeted waste from a portion of Pit 4 (DOE 2004). The enforceable schedules for submitting the draft RI/BRA and feasibility study to DEQ and EPA review were changed to August 2006 and December 2006, respectively; however, the Operable Unit 7-13/14 Scope of Work and Work Plan were not revised because tasks required to support development of the RI/FS were not formally modified.

1.4 Regulatory Background

In January 1986, hazardous waste disposal sites at the INL Site that could pose unacceptable risks to health, safety, or the environment were identified in an INL installation assessment report (INEL 1986). Sites were ranked using either the EPA hazard ranking system for sites with chemical contamination or the DOE-modified hazard ranking system for radioactively contaminated sites. A score

of 28.5 or higher in either category qualified a site for inclusion on the National Priorities List (54 FR 48184, 1989). Because several sites within the INL Site received scores greater than 28.5, the entire reservation became a candidate for the National Priorities List. The RWMC received a modified hazard ranking system score of 9.0 and a hazard ranking score of 9.0 based on the large quantities of waste and their radiological, chemical, and physical characteristics.

On July 10, 1987, the DOE Idaho Operations Office entered into a Consent Order and Compliance Agreement with Region 10 of the EPA and the U.S. Geological Survey (DOE-ID 1987). The agreement called for implementing an action plan to remediate active and inactive waste disposal sites at the INL Site under authority of the Resource Conservation and Recovery Act (RCRA) (42 USC § 6901 et seq., 1976). Generation, transportation, treatment, storage, and disposal of hazardous waste are regulated by RCRA. Sites identified for further evaluation during the INL installation assessment, including those located within RWMC, were covered by the 1987 agreement.

On November 15, 1989, the EPA added the INL Site to the National Priorities List under CERCLA, also known as the Superfund. High-priority sites for investigation and remediation of hazardous materials are identified in the National Priorities List. The decision to add the INL Site to the National Priorities List was based on detection of contaminants in the environment at the INL Site. A requirement of CERCLA is providing members of the public with opportunities to participate in the decision-making process.

The FFA/CO and its attached Action Plan (DOE-ID 1991) were negotiated and signed by DOE Idaho, EPA, and the State of Idaho to implement remediation of the INL Site under CERCLA. Effective December 4, 1991, the FFA/CO superseded the Consent Order and Compliance Agreement. The goals of the FFA/CO are to ensure that (1) potential or actual INL releases of hazardous substances to the environment are thoroughly investigated in accordance with the National Contingency Plan (40 CFR 300) and (2) appropriate response actions are taken to protect human health and the environment. The FFA/CO established the procedural framework and schedule for developing, prioritizing, implementing, and monitoring response actions at the INL Site in accordance with CERCLA and RCRA legislation and the Idaho Hazardous Waste Management Act (IDAPA 58.01.05). The FFA/CO is consistent with a general approach approved by EPA and DOE in which agreements with states as full partners would allow site investigation and cleanup to proceed using a single “road map” to minimize conflicting requirements and to maximize limited remediation resources. For management purposes, the FFA/CO divided the INL Site into 10 waste area groups. Waste Area Group 7, comprising RWMC, is located in the southwestern quadrant of the INL Site. Figure 1-1 shows the INL Site with locations of RWMC and other major INL Site facilities. Figure 1-2 provides a map of RWMC showing the SDA, the TSA, and the administration and operations area.

The FFA/CO Action Plan further divided the environmental site investigation at Waste Area Group 7 into many operable units. In the standard FFA/CO RI/FS process, potential source areas (sites) within each waste area group were assigned to an operable unit for investigation or remedial activities. This process was designed to match the rigor of the assessment process with the complexity of each individual site and to allow for flexibility in determining appropriate further action as an assessment or action is completed; however, in addition to operable units defined as specific release sites, several operable units within Waste Area Group 7 were defined as contaminant exposure pathways (e.g., air pathway and vadose zone pathway).

The RI/FS for Operable Unit 7-13, transuranic (TRU) pits and trenches, was established to investigate only those portions of the SDA containing buried TRU radionuclides. The Operable Unit 7-14 comprehensive RI/FS was designated as the final, cumulative investigation of Waste Area Group 7. Subsequently, however, Operable Unit 7-13 and Operable Unit 7-14 were combined into the single Operable Unit 7-13/14, and now the comprehensive RI/FS for Waste Area Group 7 includes the TRU pits and trenches (Huntley and Burns 1995).

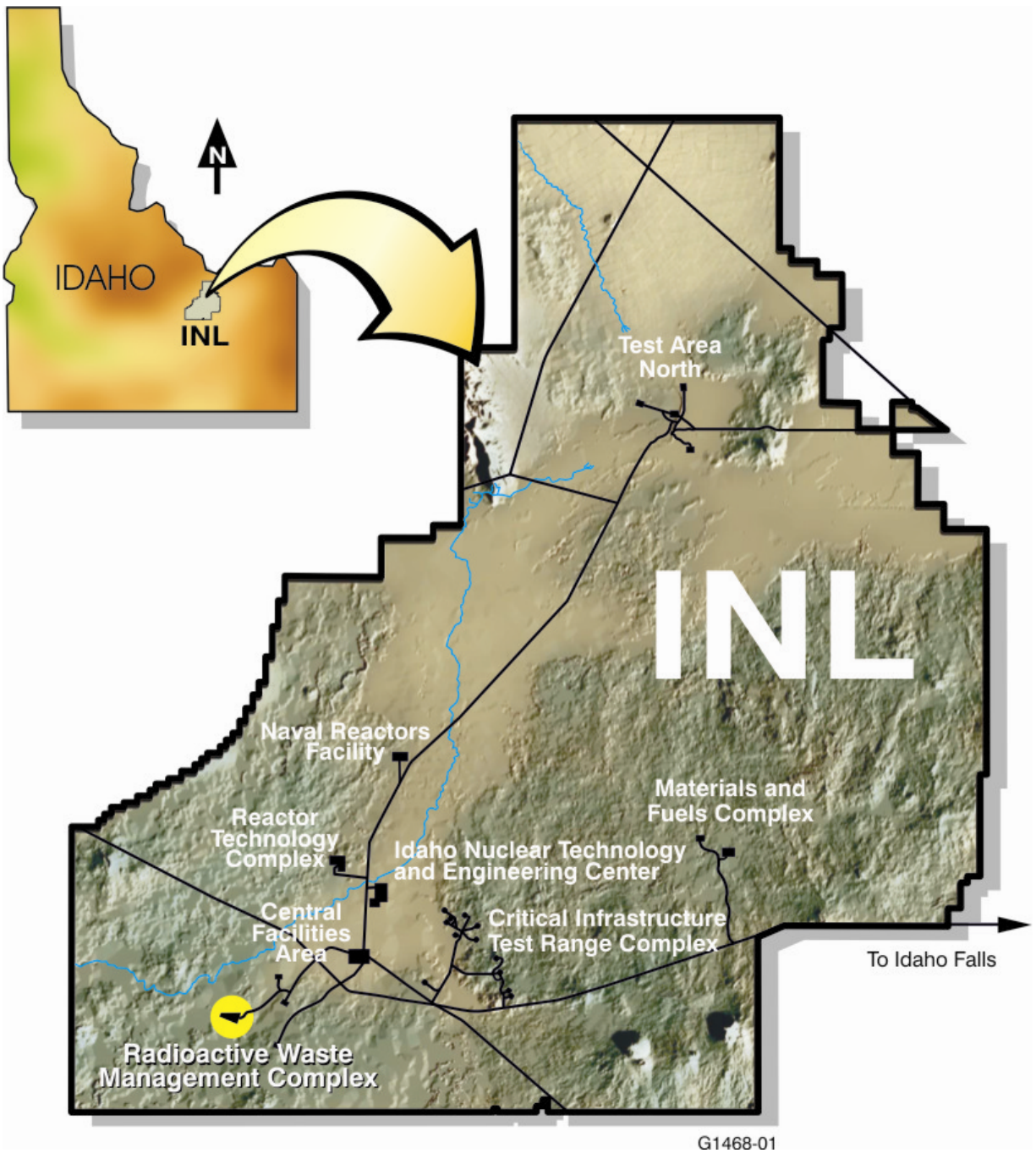
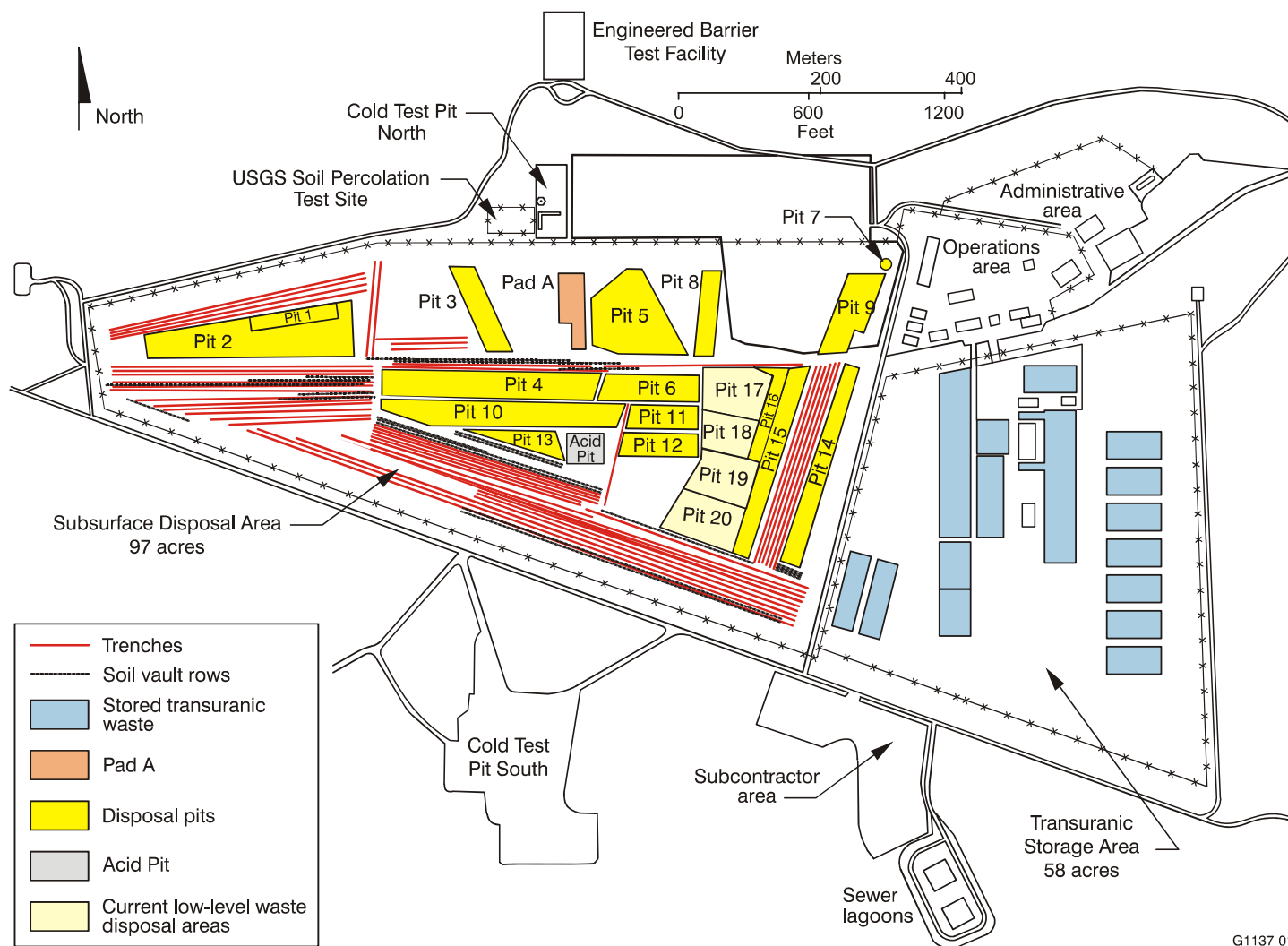


Figure 1-1. Idaho National Laboratory Site.



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Figure 1-2. Radioactive Waste Management Complex.

1.5 Report Organization

This RI/BRA contains eight sections. Individual sections conclude with references cited in that section, and a master reference list comprises the last section of the report. In addition, numerous supporting documents are available in the Administrative Record.^b The report format is adapted from the outline suggested in EPA (1988) for remedial investigations. A summary of each section follows:

- Section 1 presents introductory information for the RI/BRA.
- Section 2 describes the INL Site and RWMC, including general historical background and physical characteristics (e.g., topography, meteorology, geology, hydrology, demography, and ecology).
- Section 3 provides a synopsis of RWMC operational history and describes studies used to assess Waste Area Group 7 under CERCLA and the FFA/CO.
- Section 4 addresses the nature and extent of contamination at Waste Area Group 7 and provides descriptions of waste and results of environmental monitoring.
- Section 5 presents simulations of contaminant release from buried waste and migration in the environment. Release mechanisms, routes of migration, persistence of contaminants in environmental media, and transport mechanisms are discussed. Results from source-term modeling are applied to transport simulations to estimate potential contaminant concentrations in environmental media. A conceptual site model also is presented.
- Section 6 presents the baseline risk assessment. Deterministic risks are estimated for five human health exposure scenarios: current occupational, current residential (at the INL Site boundary), future occupational, future residential (at the SDA boundary), and future agricultural well-driller (within the SDA). Also presented are exposure assessments, media concentrations, exposure quantification, toxicity assessment and risk characterization, and uncertainties in analysis. A limited analysis of current and future ecological risks also is presented.
- Section 7 summarizes the RI/BRA, identifies COCs, discusses data limitations, reiterates remedial action objectives, and presents recommendations for the feasibility study.
- Section 8 provides a master list of the references cited in Sections 1 through 7.

1.6 References

40 CFR 300, 2006, “National Oil and Hazardous Substances Pollution Contingency Plan,” *Code of Federal Regulations*, Office of the Federal Register.

54 FR 48184, 1989, “National Priorities List of Uncontrolled Hazardous Waste Sites; Final Rule,” *Federal Register*.

42 USC § 6901 et seq., 1976, “Resource Conservation and Recovery Act (Solid Waste Disposal Act),” *United States Code*.

b. The Administrative Record is a collection of project documents and is maintained in accordance with CERCLA. The official Administrative Record is located at the INL Technical Library in Idaho Falls, Idaho. Copies of documents in the Administrative Record are located in Idaho information repositories in the Boise INL Office, the Marshall Public Library in Pocatello, the Shoshone-Bannock Library in Fort Hall, and online at <http://ar.inel.gov>.

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